BASIC TELEPRINTER AND TELEGRAPH PRINCIPLES

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PUBLICATIONS

BASIC PRINCIPLES OF A TELEPRINTER

A teleprinter is an electro-mechanical device, consisting of two parts, - a keyboard transmitter and a receiver.

Both parts are driven by a common fractional H.P. motor, this being either synchronous or governed to a constant speed (within 0.5%) as it is essential for machines at both ends of a line to be working at identical speeds, to ensure accuracy of transmission and reception, (within the limits imposed by lines which can give varying amounts of distortion to a signal).

The keyboard transmitter consists of a keyboard, similar in appearance and layout to a typewriter, on which the message is originated by an operator. Depression of any key sets up a code combination on bars which, in turn, operate an electrical transmitter. This sends suitably coded signal impulses out to a line (Fig. A) (where letter 'y' is shown being transmitted).

The line can be a physical pair of wires, a 'voice frequency' (V.F.) telegraph channel working on carrier frequencies or working into a radio link. In the latter cases the D.C. signal pulses are converted into pulses of frequency, with a 'Go' and 'Return' channel for two way working. In more complex systems, pulse sampling is introduced to allow simultaneous transmission from several teleprinters over one radio channel, and more sophisticated systems have checking and error correction circuitry embodied in them.

At the receiving end the D.C. signal pulses operate a polarised electromagnet, which controls the mechanisms required to convert the coded signals from a transmitter into a printed message on a paper roll.

The method of doing this can be seen in Fig. B. The first start signal impulse received switches on the teleprinter motor. The coded pulses set up an arrangement of levers or links, (selection action), the selector unit or sub-unit passes the selected code arrangement into a set of levers, bars or rings (translation action). Whilst the teleprinter receiver is reading off from the translation unit or sub-unit, the next incoming signal code can be accepted by the selection mechanism. It can be seen that the translator section is acting as a store, to allow the uninterrupted reception of signals coming in continuously from line.

The code stored in the translator can be a Printed Character or a Function. (A Function is an action such as Line Feed - necessary to move the paper roll up from one line to the next, or a Carriage Return, to start the printing at the beginning of a line).

The receiver mechanism has control sections which choose between a Printed Character or a Function, and the read-off from the translator operates accordingly, giving a Printed Character according to the incoming code build-up, or a Function, again according to code build-up.

The block schematics Figs. A & B show the general flow of action which is common to any teleprinter.

The 'Answer Back' unit is an optional attachment, which will transmit a station or machine identity code, when demanded by a distant machine. This assures the calling operator that he is connected to the right machine, and that it is working, even though it may be unattended. Finally it can be used for checking at the end of a message. A 'Here Is' key allows the operator to send his own identification to a distant machine.

METHODS OF WORKING

A teleprinter can be used as a whole, having a local record of transmitted messages, (Simplex working), or used as two halves, the transmit portion sending one message, without local record, whilst the receiver portion receives another message, (Duplex). The teleprinter is fitted with a 'Send-Receive' switch, which is connected in circuit for Simplex, but is omitted for Duplex (as shown in Fig. C). This switch is at rest connecting the line to the receive electromagnet, when receiving. When a key is operated from the keyboard, the S/R switch switches the transmitter to line and connects the transmitter to the receive magnet via a leak resistor, to give local record.

Two methods of transmission signalling are used. The most common method employs 'Double Current' signalling, using +ve and -ve battery supplies (approx. 80 volts) for the two signal conditions of the transmitted code elements.

The less commonly used, for short broadcast circuits or where voltage supply limitations are to be met, employs 'Single Current' signalling. Here -ve battery 'mark' is used for one signal condition working against a spring action for the 'space' signal condition.

A five unit code is employed for international working, this being known as the C.C.I.T. no. 2. code (see Fig. no. D). This code gives a total of 60 characters, as explained later, each one having different combinations of 'Mark' & 'Space' signals.

TELEPRINTER CODE & INTELLIGENCE (Fig. D)

The code used for transmitting intelligence from one teleprinter to another is 5 unit, 2 element (binary) which gives 2^5 i.e. 32 combinations. By use of 'case' shifts these 32 combinations can be used to give 64 characters, (including functions). Accepted practice is to use a -ve battery for a 'Mark' element and a +ve battery for a 'Space' element. (On single current working the 'space' battery is replaced by a spring action).

Of the 32 combinations allowed by the code, 26 are required for the normal alphabet, the other 6 are used as follows, being called 'functions'.

1. Line feed - for moving the paper to the next line.
2. Carriage return - for returning to the beginning of a line.
3. Space - for inserting a space between words or characters.
4. All space - this is a fault condition, due to possible line or power failure periods, during which the machine will run over, or 'race', as it is receiving continuous start signals. Printing and feeding of the paper must be suppressed.

5. Letter shift)
6. Figure shift)

By means of these two combinations operating a mechanical shift mechanism to the appropriate condition, it is possible to have a second group of 26 characters, (consisting of the figures 1 - 10 plus other symbols), as on a typewriter. There are therefore two 'cases', one of 26 Letters and one of 26 Figures, which are code pairs. Selection of either depends on the predetermined position of the shift mechanism. The other 4 functions are common to both cases, as also are these two.

The intelligence for the 'Answer Back' facility is the Figures case of Letter D.

The intelligence for a 'Bell' alarm contact facility is the figures case of the letter J.

STOP-START PRINCIPLE

As well as sending the code combinations, it is necessary to employ 'Stop' and 'Start' signals for control of the teleprinter clutch and motor switching actions. It is conventional to employ a 'Mark' (-ve battery) for the 'Stop' signal, and to send a 'Space' (+ve battery) for the 'Start' signal element.

This method of working ensures that receive camlines can stop and start for each character, if the receive camline is running at a slightly slower speed than the transmitter. This difference in speed prevents any phase difference between the machines (e.g. caused by motor speed variations), from accumulating and giving rise errors.

On Creed equipment transmit speed is designed at 7 or 7 1/2 units, with 6 1/2 unit receive speed.

The 7 unit transmission is now virtually obsolete. This was a C.C.I.T. standard from 1932 to 1958, although the British Post Office has always used 7 1/2 unit transmission. C.C.I.T. standard is now a minimum of 7.4 units. (This allows for slight loss of Stop Mark signal time due to S/R switch operating times, on a 7 1/2 unit time camline).

As can be seen from Fig. No. E 7 1/2 unit time gives a large synchronising pause on the receive camline, thus catering for larger speed variations and signal distortion, where extreme working conditions are likely to be met, (as on radio and long distance links used for international communications).

TELEGRAPH SPEEDS

The unit of telegraph working is called the 'Baud' and is equal to the number of signal units, or code signal element lengths, transmitted in one second e.g. 50 Bauds means that 50 code elements are transmitted in one second.

As C.C.I.T. requirements are 50 baud working, signal element length is 20 milliseconds, the time of transmission of 7 1/2 unit code is therefore 150 milliseconds.

American standards call for 45.52 bauds and many private users employ faster transmission times of 75 bauds, as they are not tied to using international networks.

The baud can be related to characters per second, or words per minute, by remembering that the average word, plus a space, is reckoned as containing 6 characters.

A telegraph speed of 50 bauds	=	6.6 characters per sec. (7 1/2 unit code)
	=	66.6 words per minute.
A telegraph speed of 75 bauds	=	10 characters per sec.
	=	100 words per minute.
A telegraph speed of 45.52 bauds	=	6 characters per sec.
	=	60 words per minute.

TELEGRAPH DISTORTION

International limits of distortion are laid down by the C.C.I.T., the limits being as follows:-

Transmission - distortion to line from a teleprinter shall not exceed 10% including all variables of motor speed, camline friction and mismatch from the teleprinter to the line impedance.

In practise this figure is usually between 5 and 7%, 3 to 5% being on the actual transmitter contacts, and 2 to 3% being due to the other factors mentioned.

Line - total line distortion shall not exceed 30%, either for single lines or lines in tandem.

In practise the majority of lines will not have distortion higher than about 10%. Long radio or V.F. telegraph systems in tandem, up to about a maximum of three systems may run up to about 25 to 30% distortion. On such systems it is essential to cut the transmission distortion to a minimum of 2 to 3% from the transmitter contacts and to keep the other variables to a minimum of about 2%.

The receive margin of distortion - this should be greater than $\pm$70%, relative to centre of normal read-off. In practise, with modern machines this is normally greater than 80% or even as high as 85 to 90%, depending on teleprinter design and maintenance standards.

Referring to Fig. E, it can be seen that a small percentage of signal element time is lost due to the transit time of the electromagnet. Also any mechanical read-off of the signal elements requires a finite time. The majority of teleprinters are equipped with an 'orientation device' which allows the read-off cam points to be moved early or late relative to the electromagnet operated times and relative to the start signal. By design, the clutch pick-up time (usually about 7 to 8 milliseconds) is allowed for so that the five code read-off points are operating in the middle of the magnet operated time. If the orientation device is moved, first early and then late, in both cases a position will be reached where the read-off occurs on the transit of the magnet, or on the signal before or after the one which it should be reading. This will give rise to the printing of an incorrect character, if e.g. a series of letters 'Y' are being received, as shown.

The orientation device is calibrated in percentage of signal length. Thus by moving the orientation device, the percentage of signal length, over which the read-off points can be moved early and late, can be measured, by observing the points at which incorrect characters are printed. It is usual to 'run out' on the letters 'R' (SMSMS code) and 'Y' (MSMSM code) employing several lines of each, and moving the orientation device slowly until about one error per line occurs.

The total percentage swing is then noted, between the two early and late error points. This represents the receive margin of distortion, giving e.g. 82% or $\pm$ 41% relative to the centre point. The orientation device should be moved to this centre point and then locked off. Any such checks must be done with transmit signals having a minimum of distortion, otherwise false percentages will be measured.

It must be remembered that most teleprinters have an orientation centre line marked, following factory build or workshop overhaul. Any field settings of the orientation device should agree approximately, within 5 - 10% of that setting. If not then there is some fault present which must be cleared.

With the orientation set for the best operating condition of the receiver, it can be seen from Fig. E (distorted signals) that, providing the signals are constant in length and providing that the receiver camline is moving at a constant speed, the read-off of the letter 'Y' shown will result in a correct print out of letter 'Y'.

However, due to governed motor speed variations and camline speed variations, from varying load or mechanical friction, it can be seen that the incoming signal edges and the receiver read-off points are both moving fractionally backwards and forwards, in time. Therefore if the incoming signal edge has moved back at the same time as the relevant read-off point has moved forward, thus with the distortion shown, it is possible for the read-off point to move to a position where it will read off into the adjacent signal element, giving an error in print out.

In such a case, where it is known that the incoming signal distortion can not be corrected quickly, e.g. due to an unvarying line fault, which cannot be cleared for several hours, or due to having a transmitter fault at an unattended station, where a mechanic must be called out, it is possible to measure the effective receive margin from line signals, and to re-centre the orientation device relative to those signals - purely as a temporary measure, in order to maintain service.

It must be remembered that the orientation device must be set back to normal as soon as the fault is cleared. This method obviously cannot be used e.g. on varying line faults such as those often met on overhead wire circuits.

The orientation device can also be used as a help in locating the position of a fault, in cases where simplex with local record working is employed (Fig. C). If both ends measure their local overall transmitter to receiver margin, and then send to one another, measuring from A - B and B - A, then, by comparing figures, it should be possible to determine which transmitter or receiver is at fault.

If the normal line condition margins are known, it may also be possible to determine if the line is faulty.

TRANSMISSION CIRCUITS (Figs. F & G)

Typical physical line and telegraph channel circuits are shown in Figs. F & G which will apply to most teleprinters. The line filters are usually Post Office type which will work satisfactorily up to a line current of not more than 23 milli-amps. (this figure must not be exceeded).

The resistance - capacitor networks shown are designed for signal wave-shaping, and the values vary with different teleprinters. The manual relevant to any particular machine should be consulted regarding these, as they play an important part in the receive margin of distortion of any teleprinter.

The line current limiting resistor R must be determined by measurement with a milliammeter for a particular line, or a particular type of teleprinter. Some teleprinter receive electromagnets require more current than others. Again reference to the particular manual should be made, although as a general rule 20 milliamps is a working figure.

Voltages are shown as + & - 80 volts. Limits of voltage here are usually between 65 & 85 volts. Barreter lamps are usually fitted in the voltage supply, as shown, to limit the current drain on the supply, in case of transmitter contacts becoming short circuited, either momentarily due to bad adjustment or a fault, or due to contacts welding together.

Normal value for the local record resistor is 3 kilohms, where such a resistor is called for, this giving approximately 20 milliamps through the local receive magnet.

Fig. G shows the waveforms through a typical telegraph channel and the normal range of frequencies employed on a 24 channel system.

The transmitter $\pm$ voltage signals operate into a telegraph channel modulator, a 'marking' signal switching the modulator to allow the appropriate channel frequency to go out to line. For international working of 50 bauds the channel band width is 120 cycles, as can be seen in the right-hand drawing. The frequencies go out through band pass filters and are combined so that up to 24 channels can be transmitted simultaneously on one high grade circuit. On lower grade circuits, only the bottom 12 frequency bands are used for a 12 channel system.

The receive signals are demodulated, after being picked off by their relevant band pass filter, the detector having A.G.C. and operating a polarised telegraph relay. The contacts of this apply $\pm$ 80 volts out to the receive teleprinter.

Maximum permissible distortion on any telegraph channel is 8%, thus allowing a maximum of three telegraph channels to be connected in tandem for long distance working.

The type of 12 or 24 channel telegraph channel system shown requires a separate transmit pair and a receive pair. In cases where a system has to work over one pair of wires, the transmit channel frequencies are made low and the receive frequencies are made high, using separation filters for the two directions of transmission. This also normally limits the number of channels available to six, or even three.

Once the teleprinter signals have been converted to pulses of frequency, it is obvious that further frequency modulation can be applied, so that telegraph circuits can be modulated to work over radio links.

Nowadays pulse sampling techniques are used for multi-channel working, allowing much larger numbers of channels to work together over any particular frequency band. Also store and check back error correction devices are used, in particular on long distance radio communication, where distortion may be high and interference problems are present. Such devices can eliminate up to 80 or 90% of errors which would otherwise occur.

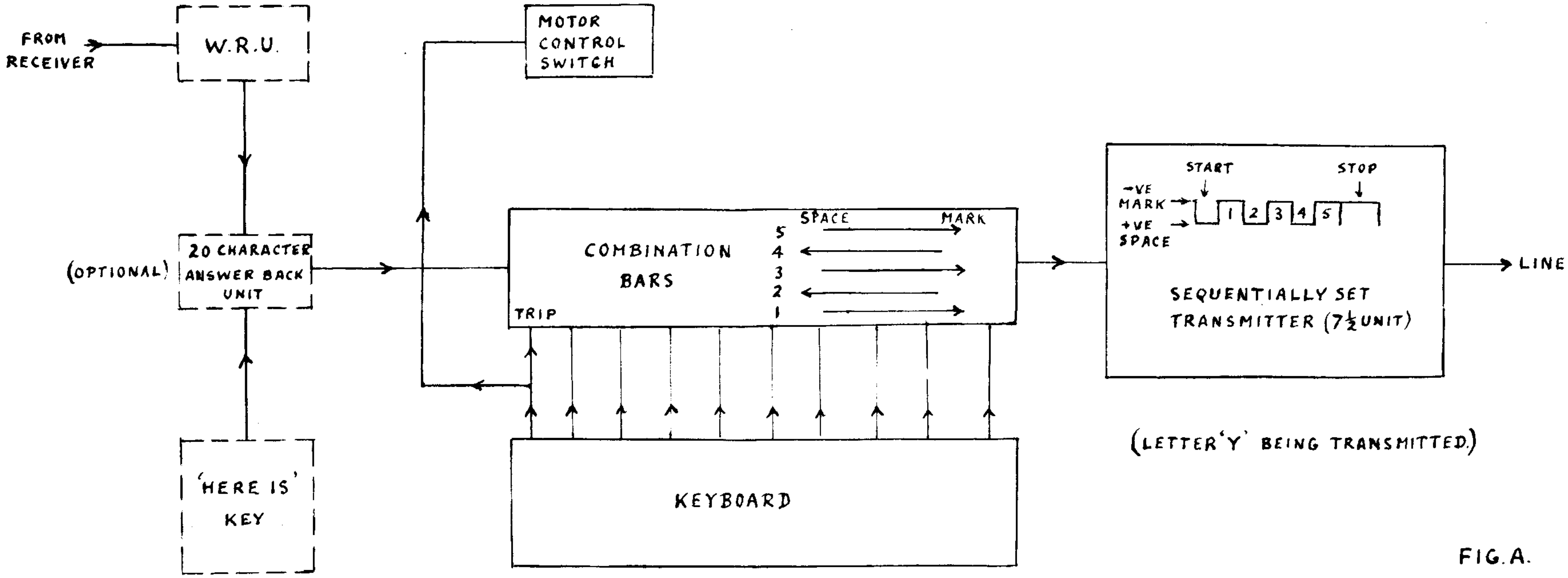

FROM RECEIVER
W.R.U.
MOTOR CONTROL SWITCH
20 CHARACTER ANSWER BACK UNIT
(OPTIONAL)
COMBINATION BARS
SPACE
MARK
5
4
3
2
1
TRIP
'HERE IS' KEY
KEYBOARD
START
STOP
−VE MARK
+VE SPACE
1 2 3 4 5
SEQUENTIALLY SET TRANSMITTER (7½ UNIT)
LINE
(LETTER 'Y' BEING TRANSMITTED)

FIG. A.

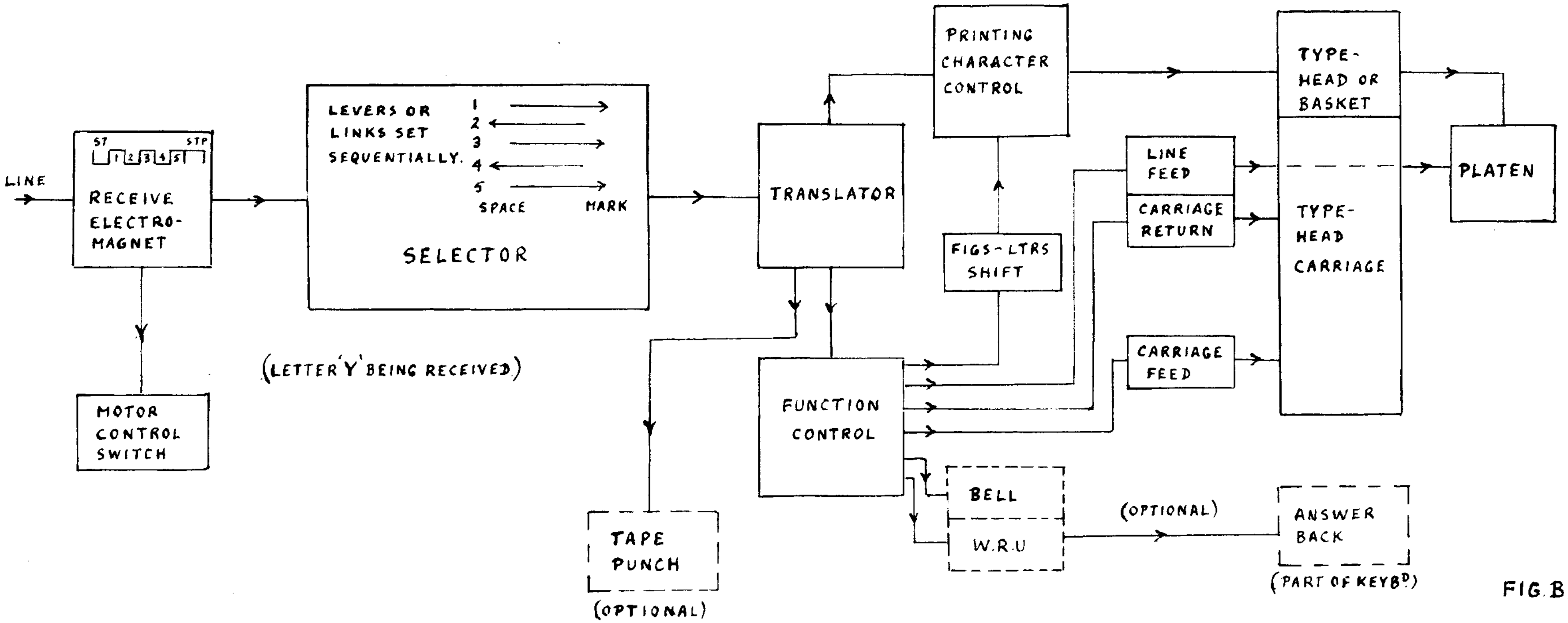
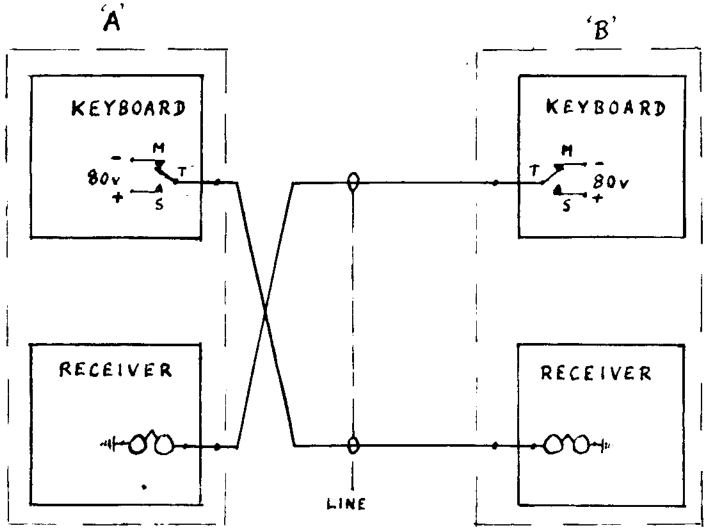
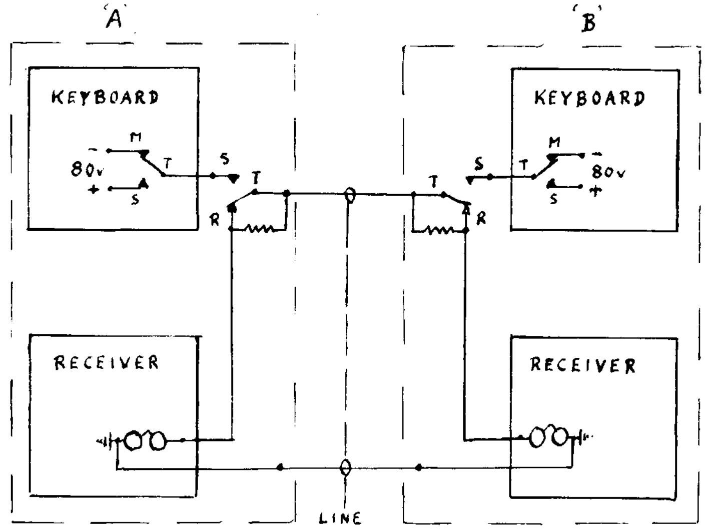

LINE
ST
STP
1 2 3 4 5
RECEIVE ELECTRO-MAGNET
MOTOR CONTROL SWITCH
LEVERS OR LINKS SET SEQUENTIALLY.
1
2
3
4
5
SPACE
MARK
SELECTOR
(LETTER 'Y' BEING RECEIVED)
TRANSLATOR
PRINTING CHARACTER CONTROL
FIGS – LTRS SHIFT
FUNCTION CONTROL
TAPE PUNCH
(OPTIONAL)
LINE FEED
CARRIAGE RETURN
CARRIAGE FEED
BELL
W.R.U
(OPTIONAL)
TYPE-HEAD OR BASKET
TYPE-HEAD CARRIAGE
PLATEN
ANSWER BACK
(PART OF KEYBD)

FIG. B.



DUPLEX WORKING.



SIMPLEX WORKING.

FIG.C.

□ SPACE ELEMENT

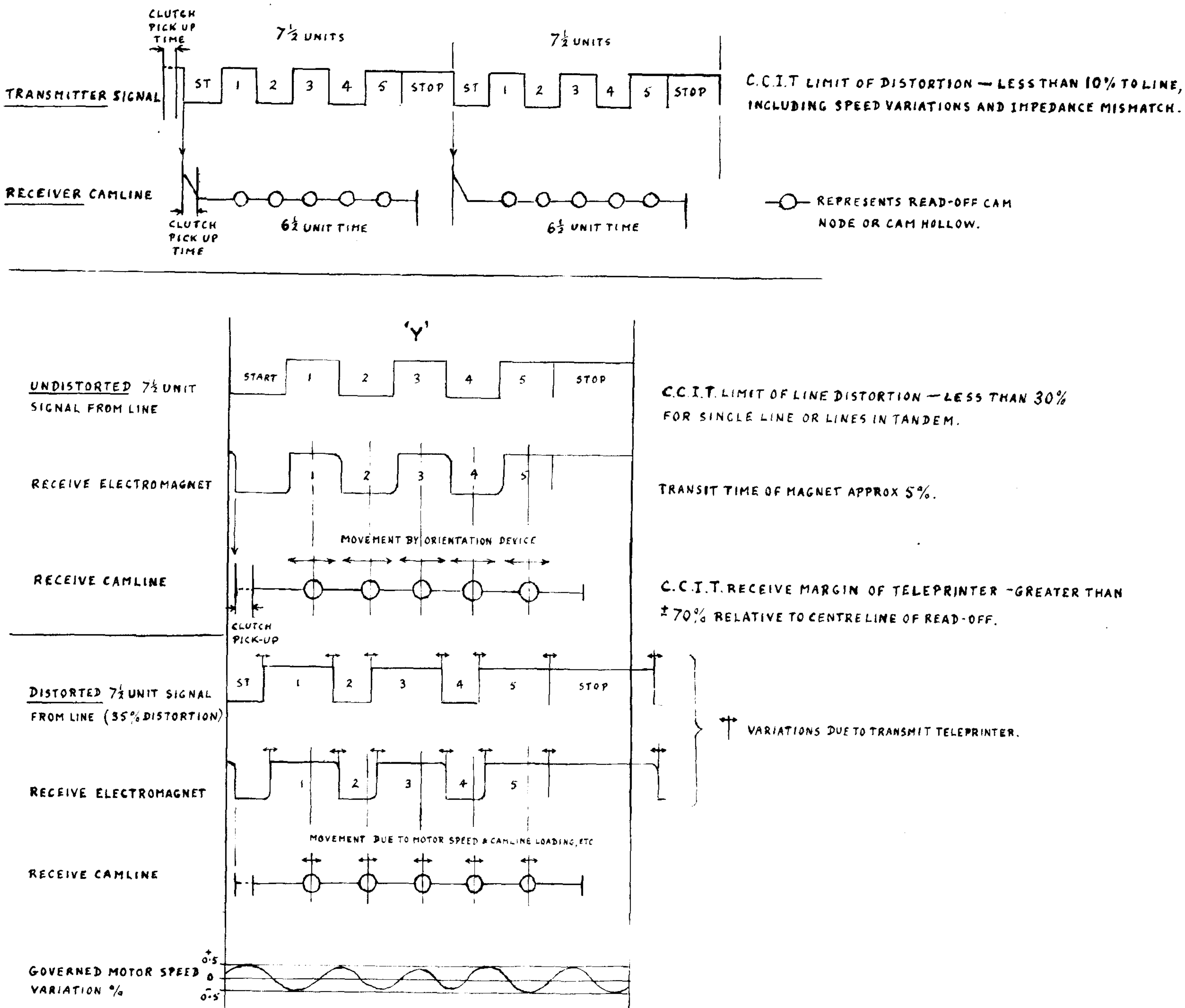
■ MARK ELEMENT

COMBN. Nº	START	CODE 1	CODE 2	CODE 3	CODE 4	CODE 5	STOP	LTRS. CASE	FIGS. CASE
1	□	■	■	□	□	□	■	A	-
2	□	■	□	□	■	■	■	B	?
3	□	□	■	■	■	□	■	C	:
4	□	■	□	□	■	□	■	D	W.R.U
5	□	■	□	□	□	□	■	E	3
6	□	■	□	■	■	□	■	F	OPTIONAL
7	□	□	■	□	■	■	■	G	OPTIONAL
8	□	□	□	■	□	■	■	H	OPTIONAL
9	□	□	■	■	□	□	■	I	8
10	□	■	■	□	■	□	■	J	BELL
11	□	■	■	■	■	□	■	K	(
12	□	□	■	□	□	■	■	L	)
13	□	□	□	■	■	■	■	M	.
14	□	□	□	■	■	□	■	N	,
15	□	□	□	□	■	■	■	O	9
16	□	□	■	■	□	■	■	P	0

COMBN. Nº	START	CODE 1	CODE 2	CODE 3	CODE 4	CODE 5	STOP	LTRS. CASE	FIGS. CASE
17	□	■	■	■	□	■	■	Q	1
18	□	□	■	□	■	□	■	R	4
19	□	■	□	■	□	□	■	S	'
20	□	□	□	□	□	■	■	T	5
21	□	■	■	■	□	□	■	U	7
22	□	□	■	■	■	■	■	V	=
23	□	■	■	□	□	■	■	W	2
24	□	■	□	■	■	■	■	X	/
25	□	■	□	■	□	■	■	Y	6
26	□	■	□	□	□	■	■	Z	+
27	□	□	□	□	■	□	■	CARR. RETN.	
28	□	□	■	□	□	□	■	LINE FEED	
29	□	■	■	■	■	■	■	LETTERS	
30	□	■	■	□	■	■	■	FIGURES	
31	□	□	□	■	□	□	■	SPACE	
32	□	□	□	□	□	□	■	ALL SPACE	

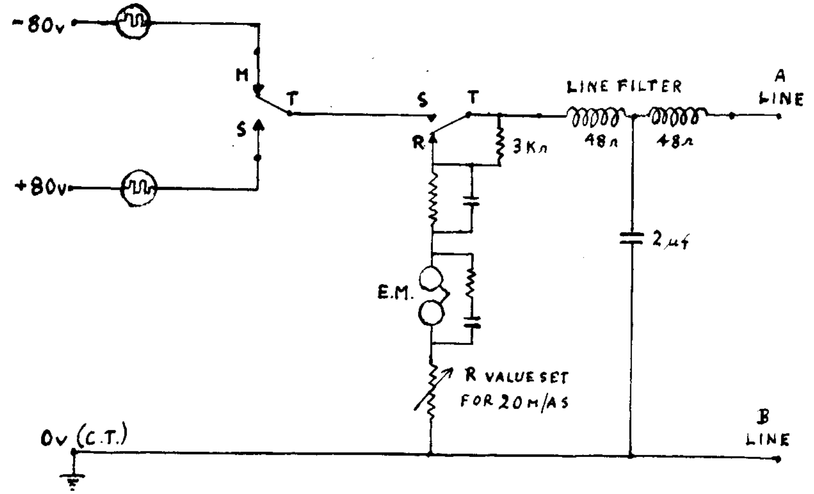
C.C.I.T Nº2
CODE

FIG.D.

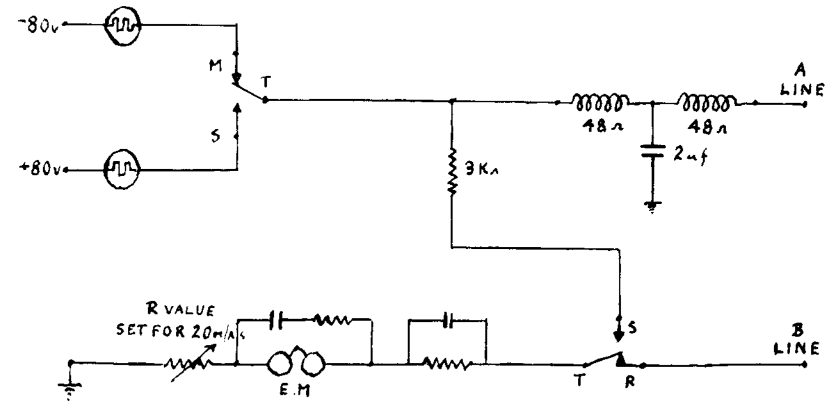


DISTORTION OF SIGNALS

FIG. E

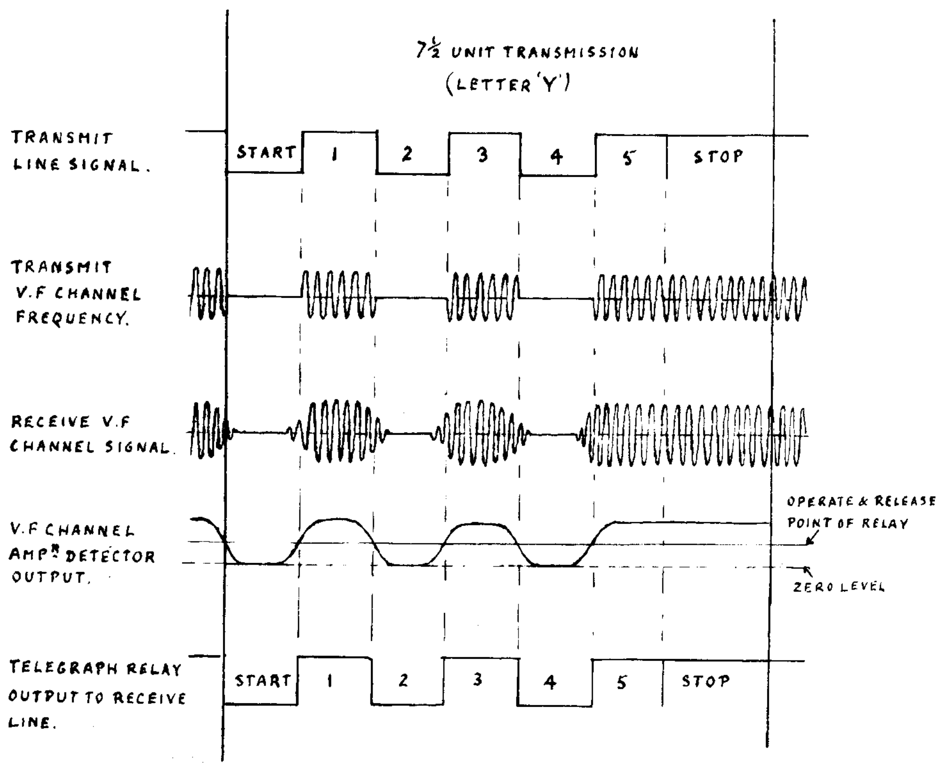


DUPLEX PHYSICAL LINE.
(WITH LOCAL RECORD)

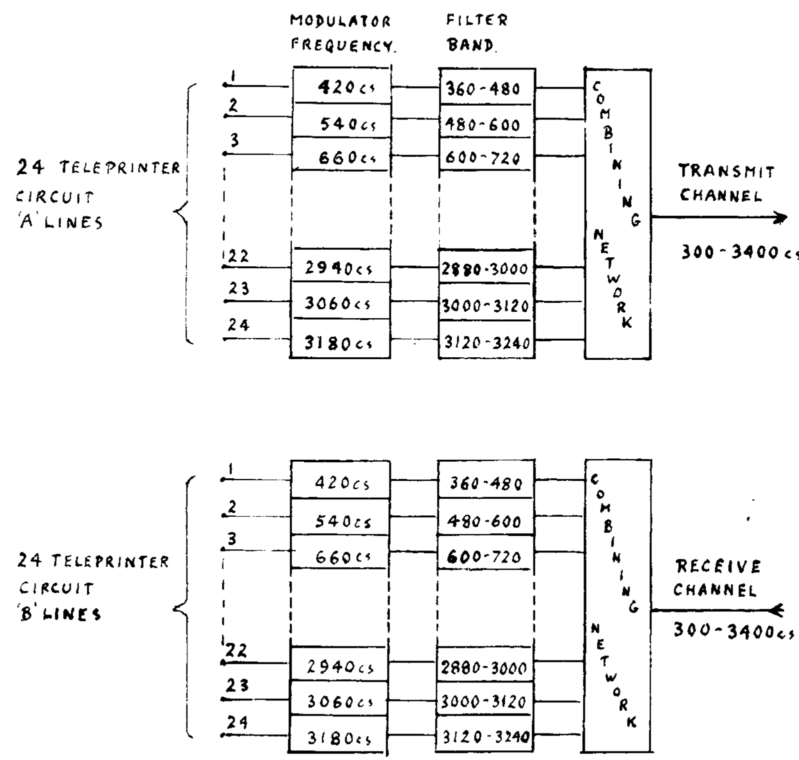


DUPLEX V.F TELEGRAPH.LINE
(WITH LOCAL RECORD)

FIG.F.



V.F.TELEGRAPH WAVEFORMS



24 CHANNEL V.F.TELEGRAPH
BLOCK SCHEMATIC

FIG G.