A technique employing frequency shift keying (FSK) method for tracking F-type Rawinsondes

S. RAMACHANDRAN

Meteorological Office, Poona

(*Received 29 April 1957*)

ABSTRACT. This paper describes a method of producing a frequency shift keying transmitter and the method of adapting it for use with the F-type rawinsonde. The frequency shift keying is produced by a short copper strip placed at a distance of two inches from the transmitter. The rawinsonde thus developed retains the essential simplicity of the single valve transmitter. Its special feature is the steady signal for direction finding, providing at the same time, the F-type radiosonde signals which are translated into the records on the paper tape as usual.

The adaptation of the rawin ground equipment SCR 658 for the F-type radiosonde was described earlier by Ramachandran and Mani (1956). This equipment has two channels, one for direction finding and the other for obtaining information on temperature, pressure and humidity from the intermittent continuous waves transmitted by the radiosonde signaller. The rawin receiver employs phasing switch for the direction finding purposes and the output of the direction finding channel is presented as 4 pips on the cathode ray tube. However, the character of the display of the signals received from the F-type radiosonde signaller would be considerably improved if the 4 pips are maintained continuously at equal heights on the C.R.T. instead of fluctuating due to the intermittent transmission from the impulse wheel. An attempt was, therefore, made to devise a method whereby the intermittent character of the received signal could be eliminated without any prejudice to the existing ground equipment through major replacements or alterations in the circuitry. The present paper describes one such method which was found successful.

The method uses a frequency shift in the signal transmitted instead of an intermittent (on and off) signal as described in the previous paper (Ramachandran and Mani 1956). The transmitter normally works at a frequency of 400 Mc/s. The radiosonde channel in the rawin receiver consists of a circuit for the reception of frequency modulated signals, the discriminator being followed by an amplifier, shaper, clipper and the recorder. If the transmitted frequency is shifted from its normal value, the discriminator gives an output proportional to the frequency shift. If a frequency shift can be produced by the meteorograph in the signaller, during the switching by the impulse wheel, at the rate of 5 to 20 per second, the output of the discriminator will be in the form of pulses suitable for the recorder. The frequency shift has to be small compared with the band width of the tuned circuits associated with the early stages of the rawin receiver in order to minimise the effects of the frequency shift on the tuning and direction finding. The required frequency shift is brought about as follows.

It is well-known that any metallic object placed in the vicinity of a tuned circuit has some effect on its resonance frequency by virtue of its capacitance effects. Fig. 1 is the circuit diagram of the transmitter. In addition to the transmitter, a metallic probe is shown connected to the H.T. negative point through the meteorograph. The meteorograph alternately grounds and ungrounds the probe by means
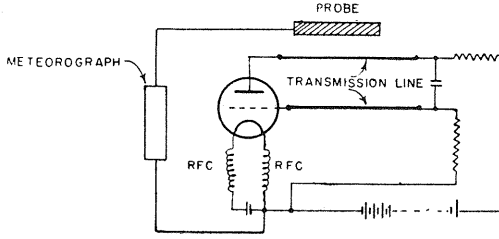
Fig. 1

Fig. 2

of the impulse wheel. The probe is a short copper strip fixed firmly at a distance of two inches from the transmission line. Let C_1 and C_2 be the capacity of the probe with the plate and grid end of the transmission line respectively.

The equivalent circuit can be drawn as shown in Fig. 2, taking into account the inter-electrode capacitances of the valve and replacing the transmission line by inductances L_1 and L_2. The lead inductances and wiring capacitances are assumed to have been included in the above mentioned parameters. The switch M replaces the meteorograph, grounding C_1 and C_2 on closing. The tank circuit essentially consists of two reactances X_1 and X_2 as shown by the dotted lines in Fig. 2. At resonance,

$$X_1 + X_2 = 0 \text{ or } X_1 = - X_2 \qquad (1)$$

When the switch M is closed, and W_1 corresponds to the corresponding frequency of oscillations, we have

$$X_1 = \frac{jW_1L_1 \times 1/jW_1C_1}{j(W_1L_1 - 1/W_1C_1)} + \frac{jW_1L_2 \times 1/jW_1C_2}{j(W_1L_2 - 1/W_1C_2)}$$

$$= - X_2 = - 1/jW_1C \quad \text{(say)} \qquad (2)$$

After simplification and substituting X for $1/W_1^2$, we get

$$X^2 - X(L_1C_1 + L_2C_2 + L_1C + L_2C) + L_1L_2(C_1C_2 + CC_1 + CC_2) = 0 \qquad (3)$$

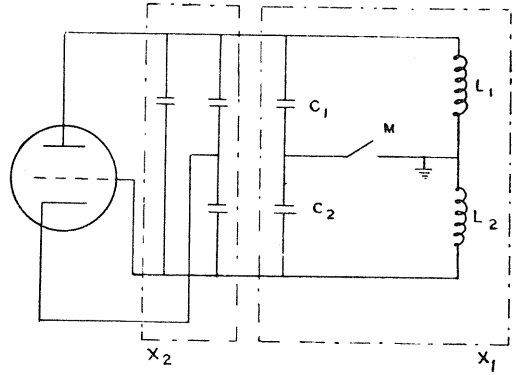To a first approximation, $L_1 = L_2 = L/2$, where L is the total inductance offered by

the transmission line across the plate and grid terminals.

Solving for X, we have

$$X = \frac{L}{2}\left(C + \frac{C_1+C_2}{2}\right) \pm \left(C^2 + \frac{(C_1-C_2)^2}{4}\right)^{\frac{1}{2}} \qquad (4)$$

C_1 and C_2 are normally small compared with C so that their difference is even smaller compared with C. Therefore

$$X = \frac{L}{2}\left(C + \frac{C_1+C_2}{2} \pm C\right) \qquad (5)$$

which shows that two modes of oscillation are possible, viz.,

$$X = L\left(C + \frac{C_1+C_2}{4}\right) \qquad (6a)$$

and $$X = L\left(\frac{C_1+C_2}{4}\right) \qquad (6b)$$

The latter mode, however, is not present since it does not produce the required phase relationship between the plate and grid voltages for the maintenance of oscillations. Thus, the frequency generated on shorting is—

$$f_1 = \frac{W_1}{2\pi} = \frac{1}{2\pi\left[L\left(C + \frac{C_1+C_2}{4}\right)\right]^{\frac{1}{2}}} \qquad (7)$$
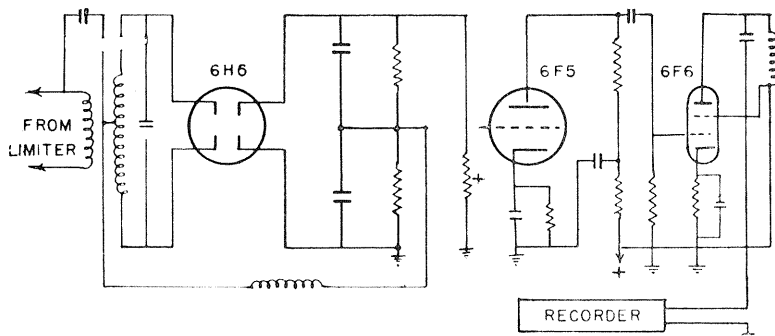
Fig. 3

Similarly, it can be shown that the frequency f_2 generated during the break period is—

$$f_2 = \frac{1}{2\pi\left[L\left(C + \frac{C_1 C_2}{C_1 + C_2} \right) \right]^{\frac{1}{2}}}$$ (8)

Now, $C_1 \neq C_2$, so that

$$\frac{C_1 + C_2}{4} > \frac{C_1 C_2}{C_1 + C_2}$$

which means that $f_2 > f_1$, $i.e.$, the frequency transmitted during the break period is greater than that transmitted during the make period.

Let, $C + \dfrac{C_1 C_2}{C_1 + C_2} = \phi$

and $\dfrac{C_1 + C_2}{4} = \dfrac{C_1 C_2}{C_1 + C_2} + \triangle$ (9)

Then $f_2 - f_1 = \delta f = f_2 \dfrac{\triangle/2\phi}{1 + \triangle/2\phi} \approx f_2 \dfrac{\triangle}{2\phi}$ (10)

From equation (9) it is obvious that $\triangle = 0$ when $C_1 = C_2$ so that $\delta f = 0$. Thus a frequency shift is possible only when the probe is placed unsymmetrically with respect to the transmission line.

As mentioned earlier, only a small frequency shift is feasible to minimise any fluctuations of the pips in the cathode ray tube. From equation (10) this means a small $\triangle$ and hence a small asymmetry of the probe with respect to the transmission line.

The probe was made of a thin copper strip of dimensions $\frac{1}{4}'' \times 1''$ cut out of a sheet of gauge 30 and was placed at a distance of $2''$ facing the valve and the transmission line.

Let us now examine the problem of getting a good radiosonde record. The input to the recorder is in the form of pulses, the recorder coil being released during periods of noise pulses and attracted back to the panel during the silent periods. Key clicks are produced when the transmitter frequency is shifted by means of abrupt makes and breaks. These large key clicks and the associated noises produced are injected back into the carrier and find their way to the discriminator. The discriminator gives positive pulses for frequencies above resonance and $vice\ versa$, the resonance frequency being 19 Mc/s. The recording circuit is as shown in Fig. 3. The grid of 6F5 tends to draw grid current on positive pulses. For good recording the receiver is tuned to the frequency f_2. Thus negative pulses are obtained during shorting periods, accompanied by the key clicks generated in the meteorograph. Thus the recorder gets input during contact periods and makes the record.

Clicks and noises were observed during the periods of long shortings of the elements of the meteorograph with the silver spiral. No compensating impedance could be introduced to eliminate this trouble. The difficulty was got over by making the plate
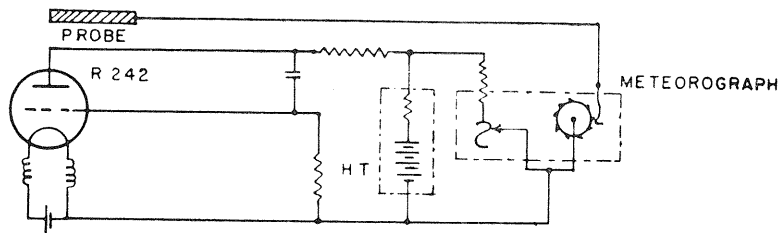
Fig. 4

supply voltage available to the transmitter lower during permanent shortings by introducing a resistance between the H.T. positive and the silver spiral and returning the body of the meteorograph to the H.T. negative. The probe was independently connected to the impulse strip (*see* Fig. 4). The extra current drawn by this resistance during the permanent shortings of the silver spiral drops an excess voltage in the internal resistance of the battery and makes the voltage available to the transmitter less. The transmitter frequency is shifted by about 500 Kc/s to the lower side. Consequently the pips on the C.R.T. come down to about half their normal height during the shortings on the silver spiral. This is no disadvantage as such shortings are of very small duration and as the pips are still available for tracking purposes.

In practice, the output of the discriminator is taken to the volume control of the radiosonde receiver (Fig. 4). The rest of the stages in the rawin receiver following the discriminator are disconnected. Transmitters of both the butterfly and the transmission line type were tried with equal success. The power supply for them could be met by means of carbon cup batteries in regular use with radiosondes. A voltage of 115 to 120 volts on no load was employed. A drop of about 10 to 15 volts occurs at a drain of 15 to 20 ma. The L.T. battery was made of Estrella cells of 15 volts each, for 75 volts. The only extra components required are two resistors.

REFERENCE

Ramachandran, S. and Mani, Anna   1956   *Indian J. Met. Geophys.*, **7**, 2, pp. 161-164.