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F.M. Deviation: Calibration and Measurement by Edge Coincidence Techniques

by

M. H. RICHES, Graduate I.E.R.E.

(Transmitter Department, British Broadcasting Corporation)

BRITISH BROADCASTING CORPORATION

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FOREWORD

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F.M. DEVIATION: CALIBRATION AND MEASUREMENT BY EDGE COINCIDENCE TECHNIQUES

SUMMARY

A measuring technique is now described which enables a deviation meter to be calibrated using an oscilloscope. This is followed by a method for measuring any given f.m. deviation on an oscilloscope with the aid of a strobe unit. The principles employed require that the carrier frequency is low enough for the operation of pulse circuits, and that the deviation to be measured is greater than 10 per cent of the carrier. Within these limitations, applications apart from broadcasting are obviously possible.

1. Introduction

Both amplitude- and frequency-modulated transmitters are used in broadcasting, and both types are adjusted to produce a specific degree of modulation when a modulating signal of standard amplitude is applied. It is therefore necessary to be able to measure both types of modulation.

The depth of modulation of an amplitude-modulated carrier can be measured without difficulty when it is displayed on an oscilloscope, but it is not so easy to measure the modulation on a f.m. carrier. What must be measured is peak frequency deviation, that is, the frequency difference between the unmodulated carrier and the maximum (or minimum) frequency that the carrier reaches during modulation.

Several methods are known for measuring f.m. deviation[1] but probably the most general arrangement uses a deviation meter calibrated by the Bessel zero method. A conventional deviation meter first demodulates the carrier, using a pulse count discriminator, then displays the peak amplitude of the detected alternating component on a meter calibrated in frequency. Thus the meter reads peak frequency deviation. The complete frequency deviation unit can be calibrated with Bessel zero equipment and a carrier (usually crystal-controlled) modulated by a good quality sine wave source.

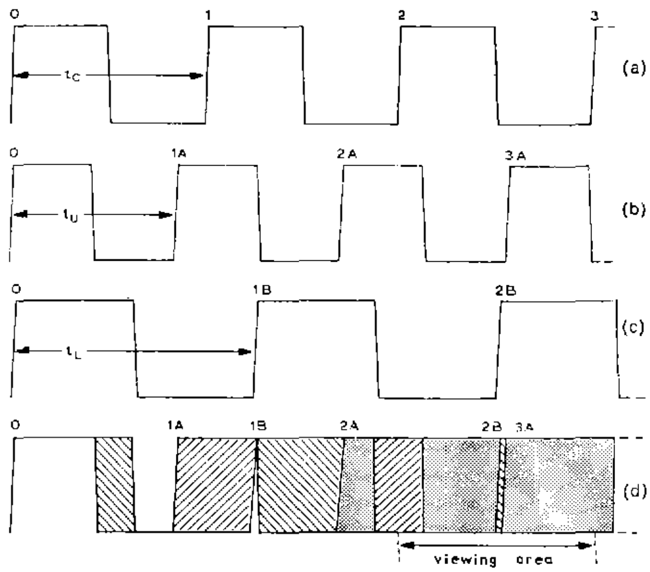

Fig. 1(*a*) *Unmodulated carrier* f_C
(*b*) *Upper deviation limit* f_U
(*c*) *Lower deviation limit* f_L
(*d*) *Display for sine wave modulation just before coincidence of edges* 2 *and* 3.
Full shading indicates overlapping areas.

2. Deviation Meter Calibration

In a conventional deviation meter, the input from the f.m. modulator will usually be mixed with the output of a built-in oscillator before being fed to the deviation meter itself, and the input to the deviation meter will therefore be referred to as the i.f. The centre frequency will probably lie in the range of 100–200 kHz, but the deviation will not have changed and a typical i.f. signal may have a deviation of ± 50 kHz centred on 150 kHz. With a low i.f. of this order it is important that the oscillator should not be pulled by the incoming f.m. signal. The i.f. signal is amplified and squared, possibly with the aid of a Schmitt trigger, to produce an amplitude limited i.f. with edges of constant rise time over the entire range of deviation. Constant rise time is essential for proper operation of the pulse count discriminator which follows the mixer and also for the method of calibration to be described. In this method, the i.f. waveform is displayed on an oscilloscope to show about three cycles, the oscilloscope being triggered from a positive-going edge. Without modulation the waveform appears as in Fig. 1(a): positive going edges are numbered consecutively and the edge '0' is that which triggers the oscilloscope. The frequency is f_C.

2.1 *Calibration with square-wave modulation*

Before proceeding to sine wave modulation the somewhat simpler results of applying a square wave are considered. The modulator output consists in the main of just two frequencies f_U and f_L, produced alternately as the square modulating waveform changes from one limit to the other. f_U is equal to the carrier plus deviation, and f_L to carrier minus deviation, i.e. $f_U = f_C + f_D$ and $f_L = f_C - f_D$, where f_D is the deviation and proportional to the peak amplitude of the modulating waveform. These two fre-

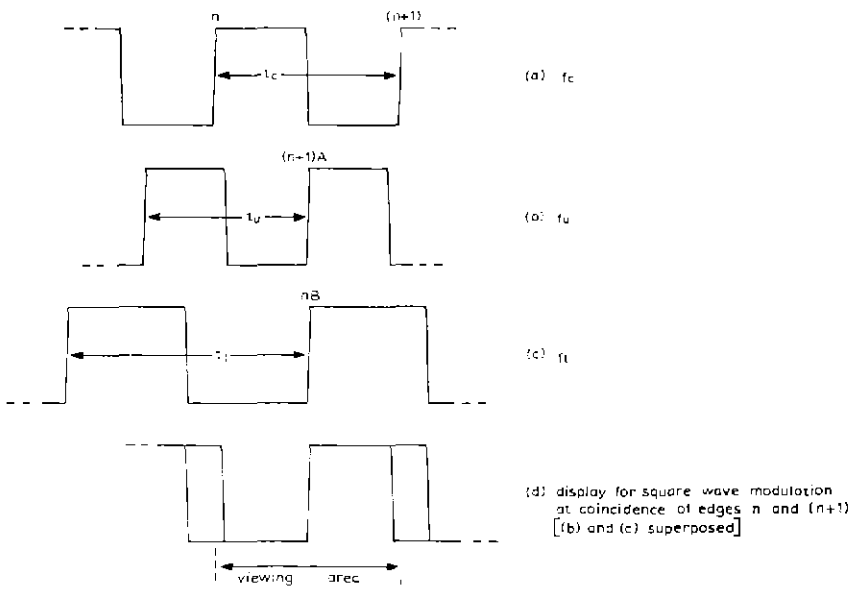

Fig. 2 Edge coincidence.

quencies are superimposed on the oscilloscope display but for clarity typical waveforms are shown separately in Figs. 1(b) and 1(c) with the edges suffixed A and B respectively. Thus as modulation is increased from zero, f_C is replaced by f_U and f_L which diverge in frequency. Deviation can be derived by measuring the time periods (t_C, t_U, t_L) of these waveforms, though with doubtful accuracy on some oscilloscopes, converting them to frequency and using the expression $f_D = f_C - f_L$. Rearranging this to

$$f_D = f_C\left(1 - \frac{t_C}{t_L}\right) \qquad (1)$$

leads to an improved method because f_C is either known to some accuracy beforehand or can be satisfactorily measured when unmodulated, and the ratio t_C/t_L can be obtained from a graticule.

A still better method is to adjust deviation until edge coincidence is obtained at particular f_U:f_L ratios, coincidence can be set with some precision because the edges are of constant rise time and superimpose exactly. f_U:f_L ratios of $(n+1)$:n where n is an integer are easily set, for example in Fig. 1 edges 2A and 1B can be made coincident providing a 2:1 ratio, or 3A and 2B for a 3:2 ratio. Fig. 2 shows the general case of first coincidence when edges $(n+1)$A and nB are time coincident, the waveforms of Figs. 2(b) and 2(c) being superimposed in Fig. 2(d). In this condition $(n+1)t_U = n\,.\,t_L$. Substituting

$$t_U = \frac{1}{f_C + f_D} \text{ and } t_L = \frac{1}{f_C - f_D} \text{ provides } f_D = \frac{f_C}{2n+1}$$

and deviation is obtained in terms of f_C the unmodulated i.f., which can be measured to any required degree of accuracy. The deviation meter can therefore be calibrated at a frequency which is an odd divisor of f_C from $f_C \div 3$ (when $n = 1$) to a practical lower limit caused by observational difficulties of about $f_C \div 41$. Coincidence always occurs midway between n and $(n+1)$ in Fig. 2(a) so a useful procedure is to make one cycle fill the screen with edge n on the left and $(n+1)$ on the right; modulation is then applied slowly to observe the first coincidence, which will occur at the centre of display as indicated in Fig. 2(d). It is important that the *first* coincidence should be observed: if edges representing differences of more than one cycle are brought into coincidence, the result will, of course, be falsified.

2.2 *Calibration with sine wave modulation*

If the modulating square wave is now replaced by a sine wave of the same peak amplitude the same peak deviation is produced so f_U and f_L are unchanged, but between these limits a whole range of frequencies is generated and Fig. 1(d) shows that such frequencies produce illuminated areas bounded by the f_U and f_L limits. These limits are very well defined and the three methods just described can still be used although there is a small error associated with edge coincidence. Sine modulation produces a more complex display than at first appears and the positive-going and negative-going edges in Fig. 1(d) representing f_U and f_L respectively do not maintain these frequencies as the display progresses to the right. Analysis of the display is not attempted here but it can be shown that errors are negligible for modulation indices greater than 10.

In a typical case where $f_D = 50$ kHz and $f_M = 400$ Hz, $m = 125$ and the error is negligible.

Fig. 1(d) shows the waveform just before edge coincidence for $n = 2$. The area of interest—which is similar in appearance for any n integer—is indicated and by use of

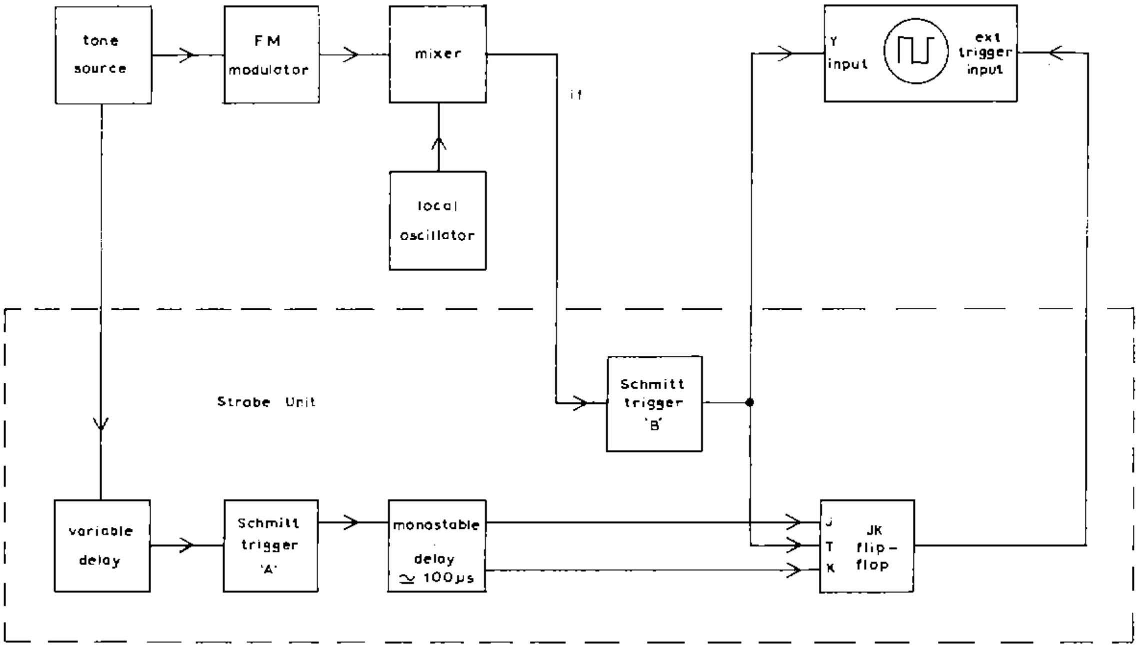

Fig. 3 Strobe method test arrangement.

X-expansion and X-shift this area should if possible fill the screen, using the unmodulated carrier as a guide, as suggested for square wave modulation. Deviation is adjusted for the minimum possible overlap between edges 2B and 3A and is seen as a thin bright line at the conjunction; deviation in this instance is then $f_0 \div 5$. The use of a constant rise time waveform ensures that edges are presented parallel to one another, a waveform lacking this quality results in edge crossover.

Coincidence can also be obtained between negative-going edges but if the waveform contains any degree of asymmetry these edges will not be placed exactly at times $0 \cdot 5t$, $1 \cdot 5t$ etc. from the '0' edge and serious errors can arise.

Under sine modulation, deviation obtained from expression (1) is practicable for values between 33 per cent f_c and approximately 10 per cent f_c; above 33 per cent the display becomes difficult to interpret and below 10 per cent, oscilloscope reading errors of $0 \cdot 5$ per cent will produce deviation errors greater than 5 per cent.

2.3 *Calibration with a separate squaring circuit*

Calibration of a frequency deviation meter by observation of its own constant rise-time waveform is both economic and convenient. However, if a suitable waveform is not available a separate limiter may be employed, and with this arrangement the technique becomes a useful alternative to the deviation meter. The modulating frequency used is not critical although for sine modulation a lower frequency produces the appearance of a more complete 'fill-in' of the illuminated areas.

Of the three methods described in Section 2.1, edge coincidence is by far the most accurate as the waveform is self-calibrating and requires no measurement, but for all of them observational difficulties prevent deviation larger than one-third i.f. from being measured and to overcome this limitation the strobe method may be used.

3. Strobe Method

The strobe unit enables any part of a f.m. wave to be extracted and displayed on an oscilloscope so that the ratio t_0/t_L can be measured and deviation obtained as before from expression (1), with the advantage that large peak deviations—approaching 100 per cent f_c—can be measured with sine or other repetitive waveforms. Fig. 3 shows the strobe unit schematic together with the complete test arrangement where it is seen that the strobe unit produces an oscilloscope trigger and a suitable display waveform. I.f. may be obtained from a deviation meter as before or direct from the mixer as shown, and the remaining input is from the tone source. The oscilloscope trigger mode is external.

The display consists of one or two cycles of i.f. similar in appearance to Fig. 1(a) strobed from a given position in the modulating cycle, their frequency depending on the deviation at that point. When the variable delay in the strobe is adjusted through the modulating time period, the displayed waveform slowly changes frequency between the limits f_U and f_L, either limit easily identifiable as a minimum or maximum waveform duration respectively. If the maximum duration t_L is placed against a horizontal scale and the modulation is then removed—while retaining a feed from the tone source to the strobe unit—the ratio t_0/t_L is measured and deviation calculated.

The strobe unit operates as follows. Schmitt trigger 'A' sets the monostable once per modulating cycle; this primes the 'J' input of the flip-flop which then sets on the next i.f. edge after this from Schmitt trigger 'B'. This triggers the oscilloscope which displays the next few cycles of i.f. After $100\mu s$ the monostable resets to its stable condition, the 'K' input becomes primed, and the flip-flop is reset by the next i.f. edge. This completes the cycle. The variable delay could enable the strobe to be set to any point in the f.m. wave but in practice the amount of delay provided need only be sufficient to identify f_L, say 60 degrees if properly centred over f_L. The monostable delay shown typically as $100\mu s$ should extend over several cycles of i.f. at minimum deviation to ensure that the flip-flop is properly triggered while the upper limit is set by the maximum modulating frequency to be used.

It is probably obvious that, as the i.f. is not locked to a multiple of the tone, the oscilloscope trigger will jitter in time according to the delay between the monostable set time and the arrival of the next i.f. edge from Schmitt trigger 'B'; if over this period the deviation changes, the displayed waveform may show a slightly thickened edge after one i.f. cycle. However, the variable delay is normally set to view f_L which is a turning point in the modulating cycle, and here the deviation is virtually constant so that although the trigger does jitter the display is clean.

As stated in the previous section, the minimum practical deviation using the ratio method is about 10 per cent f_c due to reading errors, but with the strobe method the maximum value now approaches 100 per cent f_c and reading errors assume less importance with large deviations. Again the modulating frequency plays no part in the measurement although with the low duty cycle display a higher frequency is desirable. The displayed waveform is square for ease of measurement only.

So far only the lower deviation has been measured; to measure upper deviation the expression

$$f_D = f_C\left(\frac{t_C}{t_U} - 1\right)$$

derived from (1) may be used by taking the ratio t_C/t_U after t_U has been strobed. This enables separate upper and lower measurements to be made in applications where the deviation is asymmetric.

4. Acknowledgment

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5. Reference

1. P. Broderick, **F.M. Deviation Measurements, The Radio and Electronic Engineer,** Vol. 35, No. 5, May 1968.

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