A LINEAR RADIO FREQUENCY FIELD INTENSITY METER

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In this paper the construction of a linear and stable signal strength meter is described for accurate study of radio signal strengths. A simple d.c. amlplifier has been designed for being used along with a communication receiver Type BC 348 Q. Overlapping linear ranges are provided in this meter enabling comparision of readings taken on successive ranges. The calibration curves are linear in the range of variation usually met with. A suitable micro-ammeter of range 0–60 μA with 60 divisions is used as an indicator. This instrument measures radio frequency voltages from 5 microvolts to more than 1·5 volts. The error in measurement of varying radio fields is less than 10% for recorded observations and less than 15% for visual observations. The modification of this circuit for actuating a pen and ink recorder is also described. This instrument can also be used as an r.f. microvoltmeter.

The study of the variation of field strength of a down coming sky-wave from a radio transmitter helps to understand a number of ionospheric radio wave propagation characteristics. The technique of measurement of field strength of a radio wave is fairly well developed [1,2] A field strength meter essentially consists of a radio receiver (communication type used as r.f. amplifier), a recording output meter and calibrated antenna for which the effective height is known at all frequencies so that the field intensity in micro or milli volts per meter can be determined with well known conventional methods [3,4]. Many combinations of these components are in use. The detected output is generally measured by a balanced bridge type d.c. amplifier.

The commercial field strength meters†,‡ used for such purpose have generally a logarthmic scale which is crowded at both ends and open in the middle. The non-linear scale is useful for recording roughly rapid field intensities in which the amplitude varies in the ratio 1 : 100 in a couple of seconds. This scale has the advantage of large coverage of measurement as compared to other scales but the non-linearity is often troublesome in reading the deflection accurately. The linear scale is more convenient in situations where the amplitude variations are not large and do not take place in a short interval of time. In this meter the non-linearity is eliminated with little sacrifice of the amplitude coverage ratio for recording field intensities in which amplitude variations can be adjusted from a minimum 1:10 to a maximum 1:80. Moreover, this instrument can be readily adopted for logarithmic scale measurement where such a scale is needed.

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†Ferris Meter Model No. 32.

‡Field strength Meter, Model No. FSM1, VEB WERK FUR FERMMELDEWESEN.

A simple, linear, stable and accurate instrument in conjunction with a communication type receiver (BC 348 Q) has been devised using ordinary and readily available components to overcome all these difficulties. The instrument provides a number of overlapping linear ranges employing a single tube circuit based on cathode follower principle. A V.R. tube regulated power supply is used.

CONSTRUCTIONAL DETAILS

The communication type receiver used here possesses two-stage r.f. tuned amplification preceding the first detector, a temperature compensated heterodyne oscillator, three stages of intermediate frequency (915 Kc) amplification, a second detector and finally one stage of audio amplification. Six bands are incorporated in this receiver covering the frequency range from 200 Kc—18 Mc with a gap from 0·5—1·5 Mc. The manual volume control of the receiver is fitted with a circular scale to adjust the negative bias on the r.f. and i.f. tubes. A receiver of bandwidth 10 Kc is operated in the M.V.C. position for field strength measurements. The output from the second detector is fed to one tube d.c. amplifier through a coaxial cable.

Fig 1 gives the circuit diagram of a d.c. amplifier. The detected output voltage from the receiver is applied to a grounded plate amplifier using only the high μ triode section of 6 SQ 7 tube. A suitably damped recording micro-ammeter M of range 0-60 μA with 60 divisions is used as an indicator. A provision can be made for the ready replacement of the microammeter by the multiflex galvanometer having a sensitivity of 5×10^{-11} amps/div. or any other sensitive lamp and scale galvanometer. With this new modification continuous photographic recording can be made for rapidly fading signals.

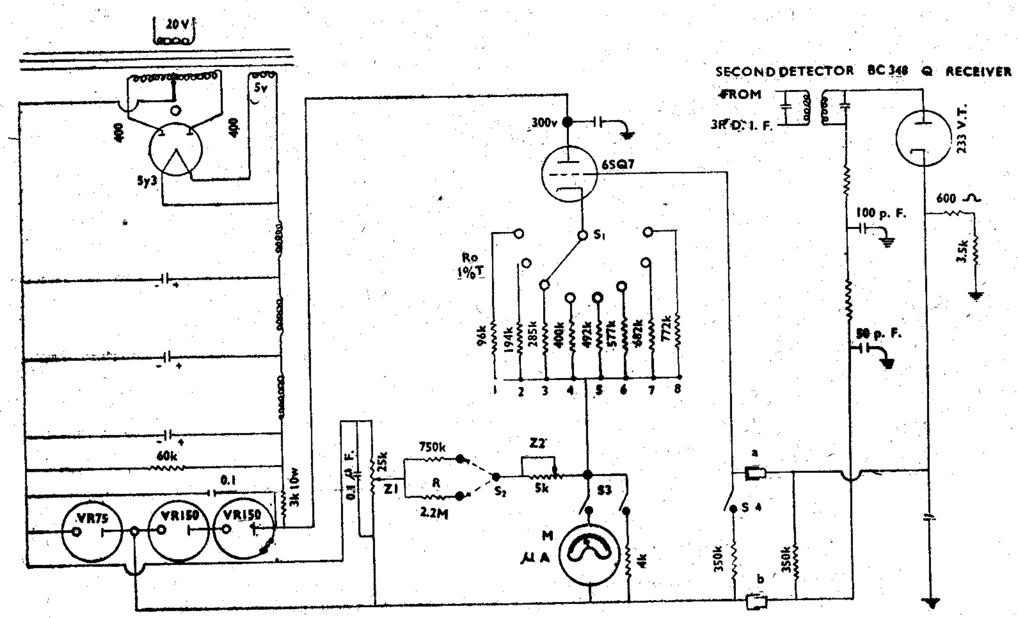

Fig 1—A linear d.c. amplifier for field intensity measurements

Out of the eight overlapping ranges (Table 1) any desired range can be selected by means of a single-pole eight-way switch S_1. The value of R_0, the cathode load resistance for each range, is so chosen that the deflection in the meter is always 50 div. when the input voltages (at points '*a*' & '*b*') are 5,10, 15, 20, 25, 30, 35 and 40 volts for ranges 1, 2, 3, 4, 5, 6, 7 and 8 respectively.

TABLE 1

RANGE DETAILS OF LINEAR d.c. AMPLIFIER

Range No.	Range (Volts)	R_o (Kilo ohms)	R (Meg ohms)
1	0—5	96·10	0·750
2	0—10	194·10	0·750
3	0—15	284·60	0·750
4	0—20	388·80	0·750
5	0—25	492·10	0·750
6	0—30	576·60	2·20
7	0—35	681·80	2·20
8	0—40	772·30	2·20

The power supply gives regulated voltage of 300 for the triode plate and —75 for cancellation of the tube current through the galvanometer. The cancellation current is fed to the galvanometer through a high resistance R (>200 times the galvanometer resistance) so that the sensitivity of the galvanometer is not affected to any appreciable extent. A coarse zero control Z_1 and a fine zero control Z_2 are incorporated in this circuit. The value of R can be changed after the sixth range with the help of the S.P.D.T. switch S_2. The S.P.D.T. switch S_3 replaces the meter by a suitable resistance of about $4K$ ohms. This is very convenient for tuning the receiver to another signal during measurements. In its absence unwanted impressions will be recorded and the meter is likely to be damaged due to large signals. The switch S_4 is used to disconnect the grid leak resistor of 350 K ohms when the d.c. amplifier unit is connected to the receiver. It is to be noted that the low potential point of the power supply of the d.c. amplifier is not connected to the ground point of the receiver. This enables positive ground end of the detected voltage to be connected to the grid of d.c. amplifier and the negative end of the detected voltage to the negative terminal of the microammeter.

The Standard Marconi Signal Generator Type 144 G is used as a calibrator. Using this generator, deflections in the recording meter for any frequency are calibrated for different positions of M.V.C. and different ranges of d.c. amplifier unit. The M.V.C. position is always adjusted such that the calibration curves are fairly linear.

WORKING OF D.C. AMPLIFIER

The functional diagram of the d.c. amplifier is shown in Fig 2. M is a linear microammeter of resistance g ohms. For a small change in the input voltage e_i to the d.c.

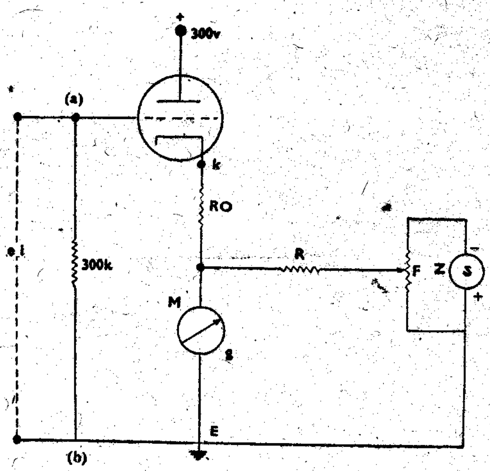

Fig 2—Functional diagram of a Cathode follower d.c. amplifier

amplifier tube, the corresponding change in tube current is given by

$$i = \frac{\mu/(R_o+g)}{\mu+1+r \quad /(R_o+g)} \times e_i$$

where μ and r_p are the amplification factor and the plate resistance. From the above equation it is seen that the current i is proportional to input voltage e_i provided the expression

$$\frac{\mu/(R_o+g)}{\mu+1+r_p\,/(R_o+g)}$$

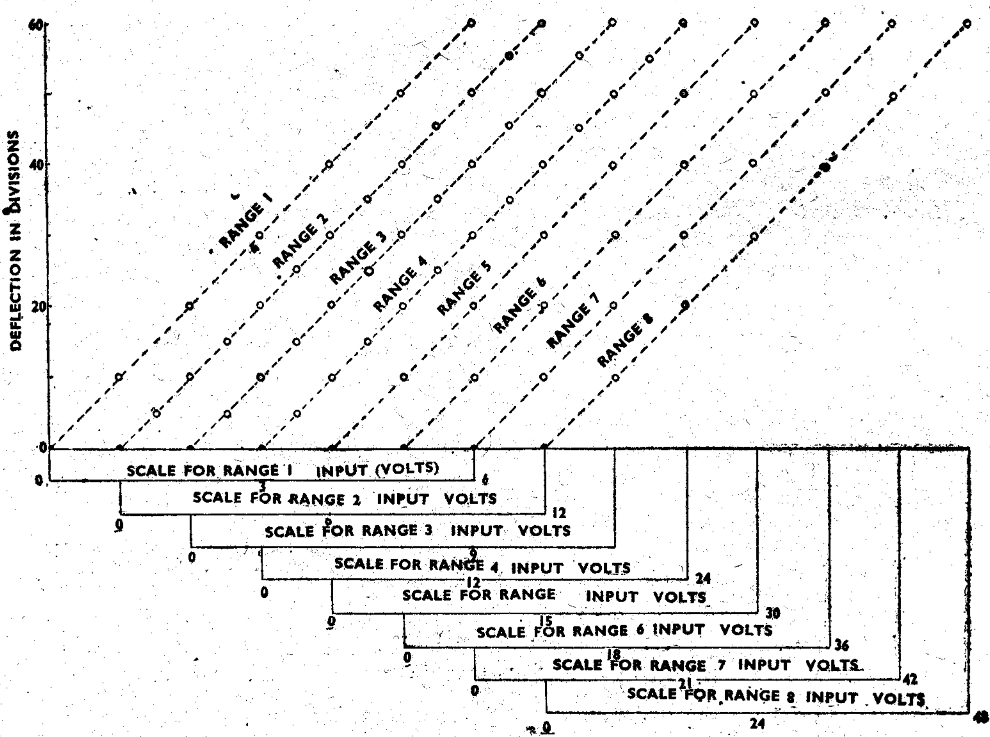

Fig 3 - Linearity curves of the d.c. amplifier remains independent of the changes in e_i . Out of the affected quantities, only r_p changes slightly with the current. If there is a 20% change in r_p , the maximum change in the expression is of the order of 0·2% because $r_p/(R_o+g)$ is nearly unity and μ is of the order of 100. Table 2 gives the calculated values of non-linearity for different values of (R_o+g). The actual experimental data is plotted in Fig. 3 from which perfect linearity is apparent.

TABLE 2

PERCENTAGE OF NON-LINEARITY IN d.c. AMPLIFIER

Range No.	R_0+g (Approx) (K)	Non-linearity (%)
1	100	0·2
2	200	0·1
3	300	0·06
4—8	—	<0·05

A similar d.c. amplifier with an important modification and based on cathode follower principle is shown in Fig 4. In this arrangement the grid leak resistance is returned to point K instead of the ground. The point K and consequently the grid point G are at a positive potential depending on the bias developed across R_k . The current in the meter is cancelled with the help of a negative constant voltage source S and a suitable high series resistance R_1 and R_2. This reduces potential of points G and K to the earth potential. This device

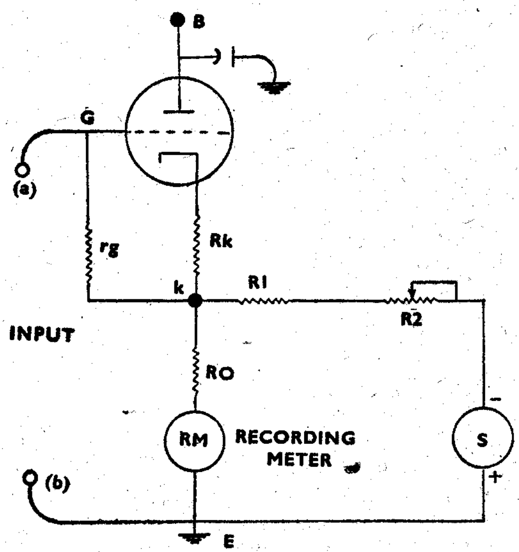

Fig 4—Functional diagram of a modified d.c. amplifier

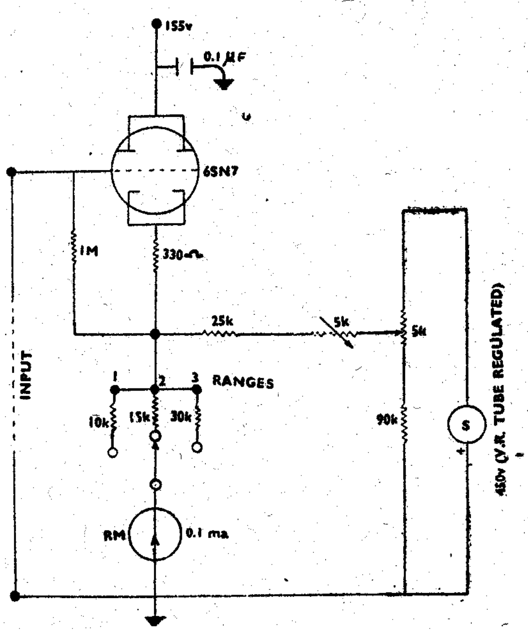

Fig 5—D.C. amplifier for actuating a pen and ink recorder

makes the input resistance of the d.c. amplifier many times larger than the grid leak resistance r_g. The input resistance of the cathode-follower is R_g /(1-A). Since A is nearly unity the factor (1-A) is small, the input resistance R_i is many times larger than R_g (if A is $0{\cdot}9, R_i = 10 R_g$). The zero drift is absent as both the ion current and the grid leak resistor are low.

MODIFICATION FOR PEN RECORDER

The recorders, which are mostly used in research laboratories, possess 0–1 milli amp./milli volt or 0—10 m.a./m.v. measuring ranges and 1–5 K resistance. A circuit using 6 SN 7 tube is shown in Fig 5. Three ranges of voltage measurement namely 0–6 V, 0–16 V and 0–32 V are obtained by selecting proper load resistances. Perfect linearity of the circuit is apparent from the calibration curves shown in Fig. 6.

ACCURACY OF D.C. AMPLIFIER UNIT

Accuracy of measurement depends on the constancy of the plate supply voltage, linearity of the recording meter and consistancy of the gain of d.c. amplifier unit. The plate voltage is maintained constant and also made independent of the mains voltage variations by the use of V.R.tubes. The reading error is 2% for full scale deflection of 50 divisions if it is assumed that an absolute error of one division is likely to be caused during quick visual recordings. The reading error increases to 10% as deflection falls to 10 divisions.

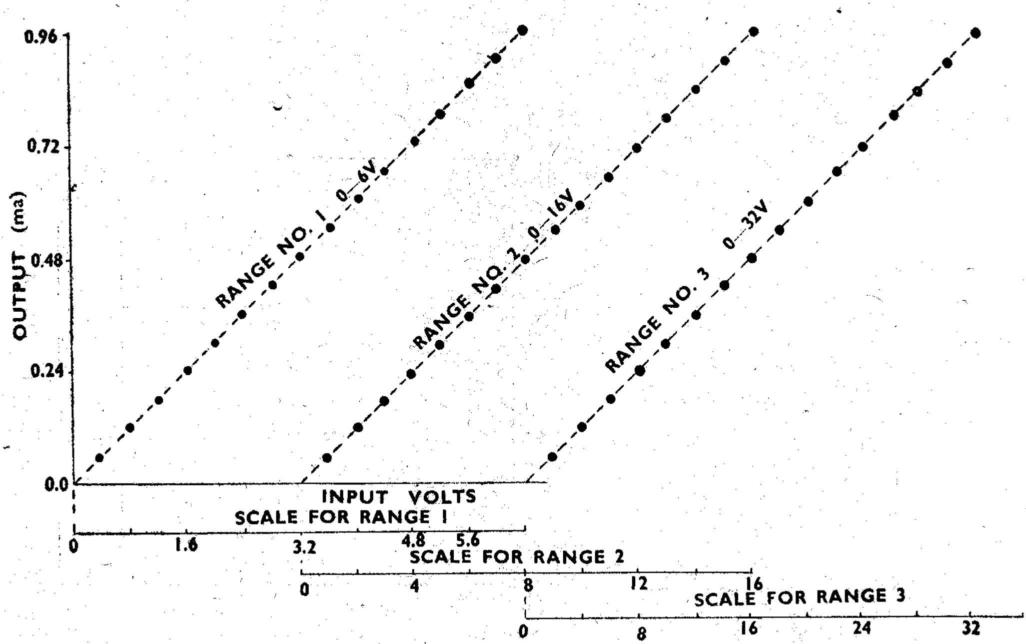

Fig 6—Linearity curves of the modified d.c. amplifier

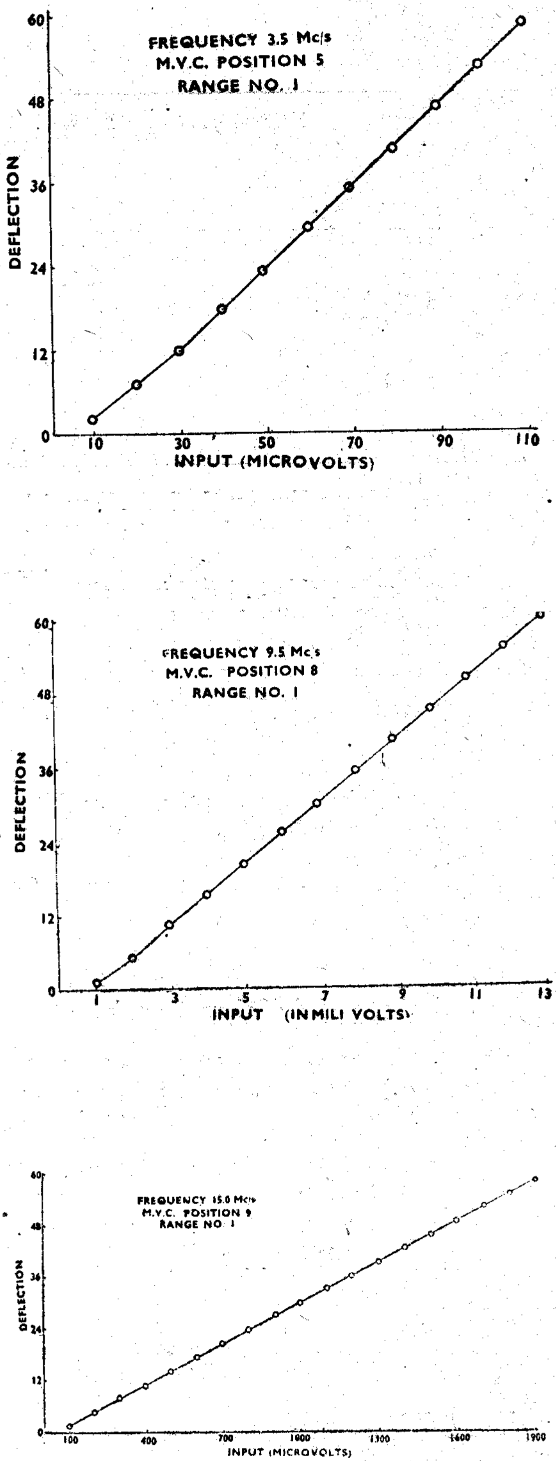

Fig 7—Calibration curves of the r.f. field intensity meter

The overall accuracy of measurement of radio frequency micro and milli volts signals depends on the following four factors :—

(*i*) Accuracy of the calibrating source.

(*ii*) Accuracy in calibrating the vertical antenna used as a collector for radio waves.

(*iii*) The stability of the radio receiver regarding its gain and oscillator frequency.

(*iv*) Accuracy and stability of the d.c. amplifier unit.

The calibration source generally employed is a Standard Signal Generator whose accuracy is $\pm 5\%$ so that the accuracy of r.f. micro voltage measurement can never be better than this value. The communication type receiver used for this purpose is stable. The recording unit is also linear and accurate.

In these measurements we see that the accuracy is mostly dependent on the calibrating source and the properties of the antenna used as a collector for radio waves and it is quite free from the associated circuits. From the above discussions the maximum inaccuracy of measurement is 15% for visual observations and less than 10% for recorded observations.

CALIBRATION CURVES AND RANGE OF MEASUREMENTS

Some calibration curves of the field intensity meter for range No. 1 at frequencies 3·5 Mc, 5·0 Mc and 15 Mc at M.V.C. positions 5, 8 and 9 are shown in Fig 7. These are linear over a large range due to proper selection of M.V.C. position. The first range 0—5 volts

TABLE 3

AMPLITUDE COVERAGE AT DIFFERENT RANGES OF R.F. FIELD INTENSITY METER AT 9·5 MCS—M.V.C. POSITION ·2.

Range (Volts)	Minimum Signal (microvolts) (a)	Deflection	Max. Signal (microvolts) (b)	Deflection	Ratio of amplitude coverage (a : b)
0—5	10	3·50	110	59·50	1 : 11
0—10	10	2·50	200	59·50	1 : 20
0—15	10	1·50	300	59·00	1 : 30
0—20	10	1·00	440	59·50	1 : 44
0—25	10	1·00	580	60·00	1 : 58
0—30	10	0·50	800	59·50	1 : 80

covers the signal amplitudes in the ratio 1 : 10 to 1 : 30 depending on the M.V.C. position. The next higher range (2nd range) covers a higher ratio of signal amplitudes 1 : 20 to 1 : 40 and so on. The details of the ratio coverage of the amplitudes at 9·5 Mc and M.V.C. position 3 on different ranges of measurements are given in Table 3. Field intensities vary rapidly during rapid fadings and may cover the range of amplitude in the ratio 1 : 100 in a couple of seconds. To cover this large scale variation a logarithmic indicator is needed. The present instrument can be made to indicate such variations as shown in Fig 8 using the non-linear characteristics of the receiver by choosing suitable position of M.V.C. control or choosing higher range of voltage measurement.

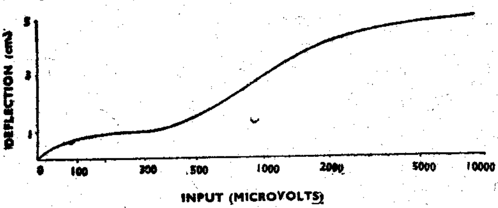

Fig 8—Non-linear characteristics of the field intensity meter.

The minimum accurately measurable r.f. voltage is 5 micro volts and maximum upto 1 volt. The stability of the instrument is remarkably good and a drift of hardly one division in the micro-ammeter is noticeable during continuous working of the instrument for a period of over 8 hours after the initial warming up period of about 20 minutes.

Here the stability of the amplifier is good because (*i*) the current in the tube is low and (*ii*) the grid leak resistor is of very low value (0·32M) so that the drift due to ion current is entirely absent.

In conventional d.c. amplifiers specially treated tubes and complicated voltage stabilising circuits are employed. Even these amplifiers are found to show drift. All these defects are completely eliminated in this instrument with simple circuitry and yet using ordinary components. This instrument can be readily used for measuring r.f. fields.

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