FM CALIBRATOR FOR DISC RECORDING HEADS

PART I

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Fig. 6. The FM calibrator ready for operation with a Scully Recorder

This is the first of two articles describing the design and construction of a successful FM calibrator.

ONE HUNDRED AND TEN YEARS have passed since the Frenchman, Leon Scott, made the first mechanical recording of sound upon a moving paper tape coated with lampblack, the sound track being engraved by a pig's bristle attached to a thin, stretched sheepskin diaphragm. Forty years later Thomas A. Edison recorded sound upon a sheet of tinfoil wrapped around a revolving cylinder. Some ten years later, Emile Berliner devised a method of recording sound upon a revolving disc.

Since the beginning of recording, the engineer has been faced with the necessity of adjusting, measuring, and calibrating the vibrating system of the recording head. For many years this was accomplished by mounting the recording head under a microscope and measuring the amplitude of stylus vibration in air at various frequencies. It was assumed that the load presented to the recording stylus by the recording material during the engraving was low relative to the mechanical impedance of the cutter. However, it is difficult to obtain accurate results with this method, especially when the amplitude of vibration is extremely small. Some workers have substituted a photocell for the human eye, thus greatly improving the accuracy.

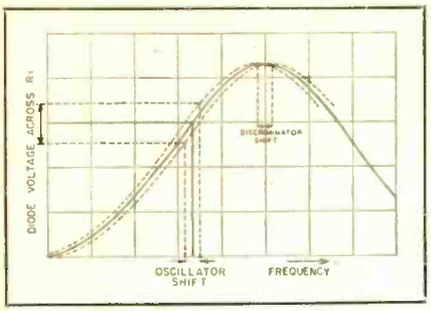
Another method of evaluating the recording head was to record various frequencies upon a disc and, by means of a calibrated microscope, to measure the groove amplitude. The most commonly used method of calibration makes use of the reflected light pattern.[1,2,3] This is accomplished by recording different frequencies on a disc and, with the aid of a light source, measuring the width of a reflected light pattern. This is fairly accurate under the proper conditions[2] and may be taken as a true indication of frequency response of the recording head.

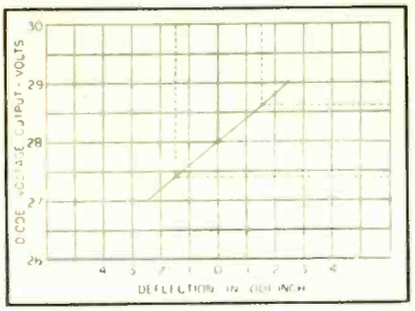
The aforementioned methods of measurement are laborious and time-consuming, and do not provide a means of measuring the distortion of the recording head nor do they permit the making of measurements while cutting a record.

FM Reproducer

Several years ago Messrs. Beers and Sinnett[4] developed a record reproducer wherein the reproducing stylus varied the capacitance of an FM oscillator-discriminator tube. The radio-frequency output of the tube was rectified and filtered, and the remaining audio component of the signal was used for reproduction purposes. Since recording and reproducing are inversely related, it was not long before Badmaieff and Roys[5,6] made use of the FM reproducer system, adapting it to the measurement of vibrating systems.

Frequency-modulation circuits in which the oscillator and the discriminator are combined in one tube can be used to convert mechanical vibrations to electrical voltage variations and can





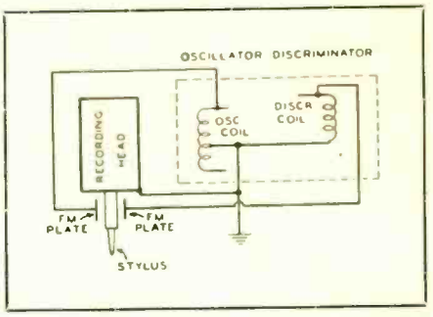


Fig. 1 (left). Graph of combined oscillator discriminator modulations in push-pull FM system. Fig. 2 (center). Linearity of push-pull FM system. (Courtesy Journal of the SMPE). Fig. 3 (right). Arrangement of FM capacitor plates.

be applied to measuring devices, reproducers, etc. Early work was confined to single-ended FM circuits where a very small capacitor plate acted as the frequency-controlling element. However, a non-linear relation existed between capacitor plate spacing and the frequency controlled by the capacitor, resulting in even-harmonic distortion. This distortion can be cancelled, although it is not easy to attain and can only be satisfied when the *change* in capacitor plate spacing is kept small in comparison with the *average* spacing. To accomplish this, and to produce the frequency shift necessary to obtain reasonable output voltage, relatively large plates must be used. In a single-ended FM circuit only one side of the movable plate is active since only one fixed plate is used, while in a push-pull arrangement both sides of the movable plate are active as each side forms one plate of two capacitors, because two fixed plates are used. This reduces the required size of the movable plate to one-half that needed in a single-ended circuit. Further reduction in size is obtained by movement in a small space, thus producing sufficient frequency shift to obtain a reasonable output voltage.

In single-ended FM circuits, either the oscillator or discriminator circuit may be modulated, the output voltage being identical in either case. In the push-pull circuit, both oscillator and discriminator are modulated 180 degrees out of phase so that the oscillator frequency shifts in the opposite direction to the discriminator resonant frequency, resulting in a doubling of output voltage for the same amount of capacitance change. This is graphically illustrated in *Fig. 1*.

Frequency modulation of the oscillator and discriminator coils is achieved through the use of a small capacitor which can be considered as a balanced split-stator unit with rotor plates so arranged that the capacitance of one section is increased while a corresponding decrease in capacitance is obtained in the other section. One section of the capacitor is connected across the oscillator coil and the other across the discriminator coil. The center plate is at ground potential. If the rotor or grounded plate is moved in either direction, the frequency changes of the oscillator and discriminator circuits will be in opposite directions, resulting in push-pull action. This push-pull action is applicable only to the capacitor. Distortion is not cancelled due to the non-linearity of the discriminator curve. To achieve the full benefits of push-pull action to reduce distortion, it is necessary that both parts of the system be closely balanced with each other. The inductances must be identical, the construction of both sides of the push-pull capacitor must be able to provide equal capacitance, equally varied in opposite directions. The linearity of the push-pull FM system was measured by Badmaieff[5] and is given in *Fig. 2*. It is seen that throughout most of its length the curve is practically linear. The total harmonic content represented by the curvature amounts to less than one per cent. The discriminator will contribute negligible distortion if the modulation is restricted to 80 kc on a 40 mc carrier frequency. The range actually used in the FM calibrator covers 30 kc in each push-pull section, thus covering 60 kc of the discriminator curve. See *Fig. 2*.

Circuit Design

The development of the push-pull FM circuit provides a solution to the problem of measuring a recording head under actual operating conditions. Here is a device that can be attached to the recorder without interfering in any way with the action of the recording stylus. As shown in *Fig. 3*, two small plates on either side of the stylus shank and insulated from each other and from the cutter are spaced several thousandths of an inch from the stylus. Nothing has been added to the vibrating system so that no change in its action can occur. Flexible leads from the plates and cutter are connected to the oscillator-discriminator unit mounted on the cutter carriage. Variation of capacitance caused by the vibration of the stylus between the plates shifts the oscillator frequency in one direction and the discriminator tuning in the opposite direction as described earlier. The audio output from the diode section of the oscillator-discriminator unit is fed to an audio amplifier through a short length of coaxial cable. The output of the audio amplifier may be measured with a suitable vacuum tube voltmeter or may be further amplified for monitoring purposes provided suitable equalization is

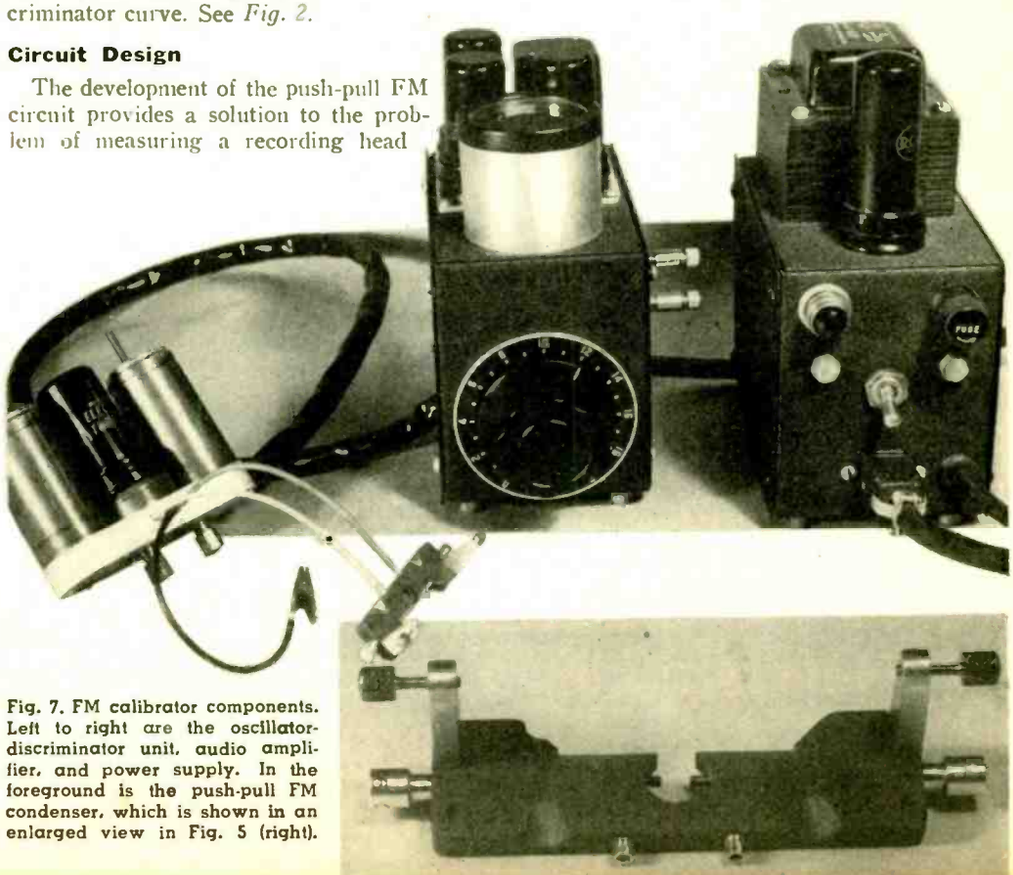


Fig. 7. FM calibrator components. Left to right are the oscillator-discriminator unit, audio amplifier, and power supply. In the foreground is the push-pull FM condenser, which is shown in an enlarged view in Fig. 5 (right).

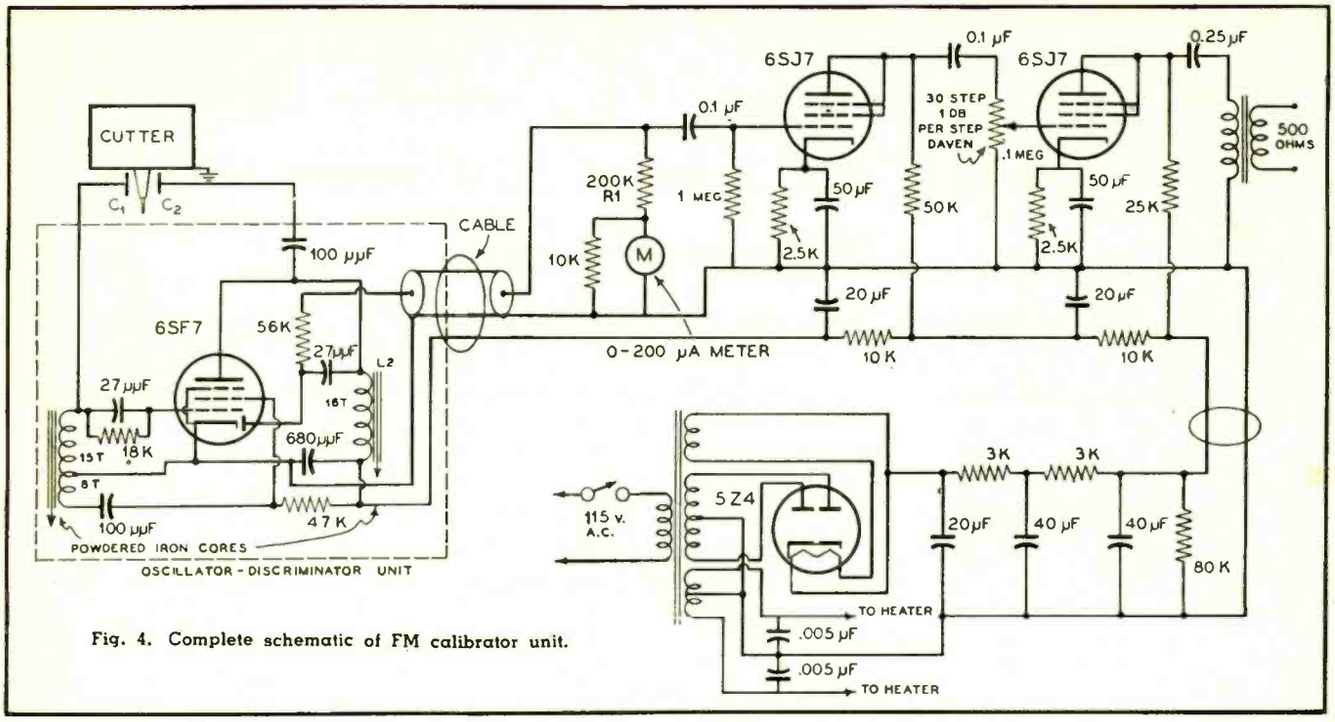


Fig. 4. Complete schematic of FM calibrator unit.

used. The complete schematic is shown in *Fig. 4*.

In the circuit of *Fig. 4*, L_1, one-half (C_1) of the push-pull capacitor, the 6SF7 grid, cathode and screen combine to form the oscillator portion. L_2, the other half (C_2) of the push-pull capacitor and the 6SF7 plate form the discriminator circuit. The two circuits are electron-coupled[7] and shielded from each other in the tube by the 6SF7 suppressor grid, which is at ground potential. The output is rectified and filtered by the diode section of the 6SF7. A 0-200 microammeter is placed in the diode circuit so that the oscillator may be tuned to the same frequency in relation to the optimum operating point of the discriminator. This is accomplished by tuning the oscillator circuit for maximum diode current and then backing down on the oscillator tuning to 70 per cent of the maximum current. If the oscillator is tuned to the wrong side of the discriminator peak, unstable operation will result. To determine the correct side of the discriminator curve, introduce some body capacitance by touching one of the leads from the FM capacitor plates and note the action of the diode meter. If the correct side of the slope has been chosen, the current will dip slightly. Should the diode current dip sharply to zero and possibly stay at zero although the body capacity has been removed indicates the oscillator is tuned to the wrong side of the discriminator peak.

The push-pull FM plates are mounted on the cutter so that the stylus is centered between them. *Figure 5* shows the push-pull FM capacitor unit consisting of a ⅛" thick Bakelite bracket in which are mounted two 0-80 machine screws which serve as the capacitor plates. The micrometer knobs with which the plate spacing may be adjusted are shown at each end of the Bakelite bracket and are insulated from the capacitor plate screws by small polystyrene rods. Contact is made from the capacitor-plate bushing to pin jacks mounted in the side of the bracket, flexible leads of 4-mil steel wires, covered with vinyl tubing and mounted on lucite spacers from the pin jacks to the oscillator-discriminator section which is supported above the cutter by a bracket clamped to the recorder carriage.

Oscillator-Discriminator

The oscillator-discriminator unit must be built as rigidly as possible to provide stability of operation. The chassis is milled out of a block of dural, while the coil shields are ⅛ in. wall brass tubing. The iron-core adjusting screws are accessible from the top of the coil shields. Connection is made to the audio amplifier through a short flexible length of cambric tubing which carries the co-axial line and the necessary plate and filament voltages. The power supply has been built on a separate chassis to avoid hum pickup in the audio system. *Figure 6* shows the complete unit set up for operation. It might be mentioned at this point that a frequency run and distortion check can be made almost as quickly as the operator can change the audio oscillator and read the calibrator output.

The FM calibrator was designed originally as a laboratory instrument for the calibration and adjustment of recording heads. The model illustrated was designed primarily as a maintenance tool for making periodic frequency and distortion checks on the recording heads in the studios. The FM calibrator also lends itself admirably to the making of test frequency records.

Construction details of the push-pull FM capacitor assembly, the oscillator-discriminator unit, and the associated mounting brackets as well as applications of the FM calibrator will follow in subsequent issues.

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