UDC681.846.7 **GERMAN STANDARD** **1957 September**

*Magnetic Tape Sound Recording* **DIN 45 520**

# Method for Measuring the Absolute Magnitude and Frequency Response of the Flux on Magnetic Tape*

## 1 DEFINITION OF THE FLUX OF MAGNETIC RECORDING TAPE

The general theory of permanent magnets applies to the remanent magnetization on magnetic recording tape. The magnetic flux of the magnetic recording tape $\Phi$ is the parameter to be specified. It is expressed as an rms value in the SI unit webers [Wb].

## 2 MEASURING THE ABSOLUTE MAGNITUDE OF THE FLUX

### 2.1 Direct AC Method

The absolute magnitude of the flux can be determined in practice by reproducing the tape with a head whose electromagnetic sensitivity in volts per weber is known at a specified wavelength and frequence (see §3). If some other wavelength and/or frequency is used, then the frequency response of the tape flux has to be taken into consideration (see §5).

### 2.2 Transfer-to-DC Method

The absolute magnitude of the flux can also be determined at long wavelengths with a sensitive iron core magnetometer with a test gap, or with a Hall-effect transducer whose sensitivity is known (see §3).

### 2.3 Same-Tape-Transfer Method

The flux can also be determined without separately measuring the transducer sensitivities mentioned in §2.1 and §2.2 by reversing the measurement procedure described in §3. This will be described in §4.

*Note*: This method avoids measuring errors that could arise from a transducer whose sensitivity is dependent on the type of tape.

## 3 DETERMINING THE ELECTROMAGNETIC SENSITIVITY OF A TRANSDUCER

The electromagnetic sensitivity of a particular transducer is determined by means of a recording having a known flux. For the direct ac method of §2.1 one can use a tape recorded as described in §3.2, or the reference fluxivity section of the calibration tape as described in DIN 45 513. For the transfer-to-dc method of §2.2, a tape is recorded as described in §3.1.

*Note*: Symmetrical recording around the zero point is necessary for an accurate measurement. Careful demagnetization of the head and the tape guides is therefore necessary, as well as the absence of even-order harmonics in the bias current and the erasing current.

### 3.1 Making a Recording with a Known DC Flux

A recording is made with direct current on a magnetic tape meeting the specifications of DIN 45 512 by using a magnetic recorder that meets the specifications of DIN 45 511 and whose recording head can also receive direct current (recording current of zero frequency). The value of the flux should lie somewhat below that for the "maximum recording level."[1] The high-frequency bias current that gives the usual operating point[2] is to be superimposed on the direct current.

*Note*: By reversing the direct current one can determine whether the requirement of symmetry is met.

#### *3.1.1 Determining the Value of the Flux*

One section of the recording produced by the method of §3.1 is cut by a nonmagnetic tool into short strips which are fastened in a bundle. The flux of this bundle can be measured directly with a search coil (see §3.1.1.1) or from the magnetic moment with a magnetometer, or in a homogeneous magnetic field (see §3.1.1.2). In any case, however, one must be sure before the measurement is made that the direction of the remanent magnetization deviates no more than 10° from the longitudinal direction of the bundle. This may be done

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[1] *Editor's note*: The "maximum recording level" is defined in DIN 45 512, pt. 2, "Magnetic Tapes, Recording-Performance" (1959 Feb. and 1975 Apr.) for professional use at 190- and 380-mm/s tape speed, as the fluxivity for 3% third-harmonic distortion.

[2] *Editor's note*: We assume that the "usual" biasing point means biased for maximum recording sensitivity at 1000 Hz.

by suspending the bundle in a homogeneous field without any applied torque.

### 3.1.1.1 Determining the Flux by Means of a Search Coil

The search coil has to be so constructed that it will enclose the total flux. For this reason the length of the tape pieces should be at least five times the length of the coil, and the coil opening should fit the tape bundle as tightly as possible. The ratio of the width of the tape bundle to its length should be about 1:100. The voltage induced by pulling the bundle from the coil is determined by means of a ballistic galvanometer, a flux meter, or an integrating amplifier and a peak reading voltmeter.

When a ballistic galvanometer is used, the flux $\Phi$ of the recording is then given by

$$\Phi = \frac{\alpha K}{Nn} [\mathrm{Wb}] \qquad (1)$$

where $\alpha$ is the meter deflection in scale units, $n$ is the number of tape pieces in the bundle, $N$ is the number of turns on the coil, and $K$ is the sensitivity constant of the measuring equipment[3] in webers $\times$ turns per scale unit.

### 3.1.1.2 Determining the Tape Flux from the Magnetic Moment

The tape bundle is suspended within a uniform magnetic field of known strength $H$, such as in a Helmholtz field. The uniformity of the field in the measuring area should be kept within $\pm 0.5\%$, and the field strength $H$ should at no time exceed 10% of the coercive force of the tape used. The bundle consists of from 10 to 20 pieces about 60 mm long, and is suspended at right angles to the direction of the field. The rotational torque resulting from switching on the field is determined by means of a known restoring torque. If, for instance, $n$ parallel tape pieces of length $l$ and weight $W$ are suspended from two parallel threads whose own rotational torques are negligible, of length $h$, and a distance $d$ apart, and the angle of rotation is determined with a lightmeter device (scale deflection $\beta$ at a distance $b$), then the tape flux is given by

$$\Phi = \frac{Wd^2\beta}{8Hlbhn} [\mathrm{Wb}] \qquad (2)$$

where $\beta$ is the average value of deflection using two results obtained from opposite field directions (lengths including $\beta$ in meters, $W$ in newtons, and $H$ in amperes per meter). The rotational angle must not exceed 10°.

## 3.2 Making a Recording with Known Alternating Flux

A recording is made under the same conditions as described in §3.1, using the same conditions (especially with regard to the value of bias current), except that now the frequency of the recording current should correspond to the reference frequency for the appropriate tape speed. The ratio of the rms value of the flux of the recording thus produced, to the value of the flux of the corresponding direct-current recording as measured in §3.1.1 is the same as the ratio of the rms value of the ac recording current to that of the dc recording current used in §3.1. They should be below the value for maximum recording level, and about equal. The correction factor for the wavelength response from an infinite wavelength to the wavelength corresponding to the reference frequency must be taken into consideration. This must be determined, for the system used, by calculation from an approximate theory[4]; the correction is about 0.5 dB.

## 4 SAME-TAPE-TRANSFER DETERMINATION OF THE TAPE FLUX

Taking into consideration the pertinent factors described in §3, the recording to be measured is reproduced with a reproducing head. This recording is erased, and an alternating magnetization is recorded on the same piece of tape using the same frequency and about the same intensity. The tape is again erased, and a direct magnetization is recorded with an equivalent direct current. The flux is then determined by the method of §3.1.1. By correcting for the ratio of the recording head currents, and the ratio of the reproducing voltages, the measured flux may be related to that of the original recording to be measured.

## 5 MEASURING THE TAPE FLUX VERSUS FREQUENCY

The tape flux versus frequency of a test sample recording is measured by using the principle that when a tape recorded with constant flux at various wavelengths is reproduced with an "ideal magnetic reproducing head," the head emf (the open-circuit output voltage) will rise at 6 dB per octave with decreasing wavelength. The practical magnetic reproducing head used for this test will have some loss.[5] Therefore the open-circuit voltage of the reproducing head must be corrected for its losses, and then compared with a voltage that rises 6 dB per octave.

The losses of a practical reproducing head are due to the fact that the gap length is not in general short enough

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[3] For the determination of the constant $K$ see, for example, F. Kohlrausch, *Praktische Physik*, vol. 2, 19th ed. (Teubner Verlagsgesellschaft, Leipzig, Germany, 1950), p. 83 ff. *Editor's note*: The ballistic galvanometer is only of historical interest, being replaced now by electronic instruments. For an English-language reference, see F. K. Harris, *Electrical Measurements* (Wiley, New York, 1952), chap. 8. The section on galvanometer calibration (pp. 366–367) explains a general method for using a mutual inductor to calibrate any kind of search-coil fluxmeter.

[4] *Editor's note*: The German says "by extrapolation," which is meaningless here because nothing is given to extrapolate from. The translated phrase is based on the practice given in the background papers for this standard.

[5] The term "loss" refers to any deviation of the response from the ideal.

and its surface contacting the tape is not long enough in comparison with the wavelengths to be reproduced, and that eddy-current and hysteresis losses, winding resistance, self-capacitance, and leakage inductance are also present. When using a suitable head design, the latter can generally be neglected, but the gap-length and eddy-current factors must be considered.

Finally, when reproducing long wavelengths the errors arising from the finite length of the contact surface must be corrected.

### 5.1 Determining the Gap Loss

Gap loss is dependent on the recorded wavelength $\lambda$. A swept frequency is recorded on a high-coercivity tape at a slow tape speed at the greatest possible flux without causing "bias beat" distortion. This recording is reproduced. The longest wavelength is measured at which a null point of the open-circuit voltage of the reproducing head can be found. The wavelength of this null in the output[6] is the null wavelength $\lambda_n$.

The gap loss function for the necessary correction is

$$k(\lambda) = 20 \log \frac{\pi\lambda_n/\lambda}{\sin(\pi\lambda_n/\lambda)} \text{ [dB]} .$$

The reproducing head gap length used for the measurement must be short enough so that the gap-length correction does not exceed 5 dB. Further gap losses occur through faulty gap construction such as nonparallel or rounded edges and poor contact between magnetic tape and reproducing head.

*Note*: These factors are seen as a broadening of the null. They cannot be determined numerically at this time, but can be kept sufficiently small by use of a suitable head construction and a choice from a number of head samples.

### 5.2 Determining the Eddy-Current Losses

To determine the eddy-current losses, position a conducting loop parallel to the reproducing gap of the reproducing head. Apply a constant current at all frequencies, of such magnitude that it induces in the head a voltage equal to that from the reference fluxivity of the calibration tape of DIN 45 513. The deviation of the frequency response of the reproducing head voltage from a straight line increasing 6 dB per octave is the correction function for the eddy-current losses.

### 5.3 Evaluation

The reproducing head emf obtained by reproducing a test sample is corrected by superposition for the gap loss as a function of wavelength, as determined in §5.1; and for the eddy-current losses as a function of frequency, as determined in §5.2. The result represents the emf obtained with an "ideal reproducing head." The difference between this curve and a straight line with a slope of 6 dB per octave is the tape flux versus frequency, as defined in §5.

## APPENDIX
## REFERENCES ADDED IN TRANSLATION

This standard is based mainly on two papers by O. Schmidbauer, which themselves give many references to previous work:

O. Schmidbauer, "Determining the Magnetization of Magnetic Tape," translated from "Zur Bestimmung der Magnetisierung auf Tonband," *Elektron. Rundsch.*, vol. 11, pp. 302–305 (1957 Sept.), *J. Audio Eng. Soc.*, vol. 46, this issue.

O. Schmidbauer, "Determining the Frequency Response of the Magnetization of Magnetic Tape," translated from "Zur Bestimmung des Frequenzganges von Tonband-Magnetisierungen," *Elektron. Rundsch.*, vol. 11, pp. 373–375 (1957 Dec.). (Available in draft English translation from Magnetic Reference Lab., Mountain View, CA.)

The later issue of this standard, dated 1973 January, renumbers §3.2 as §3.3 and adds a new §3.2, which describes a flux measurement that uses a very long-wavelength (4 m) recording, based on H. Link, "Verfahren zur Ermittlung des Absolutwertes des remanenten magnetischen Bandflusses auf Magnetband" ("Method for Determining the Absolute Value of the Remanent Magnetic Tape Flux on a Magnetic Tape"), Rep. 185, Institut für Rundfunktechnik, Munich, Germany (1968).

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[6] This measurement of null wavelength $\lambda_n$ includes the effect of any gap irregularity. *Editor's note*: Later research has shown that a small correction should be applied due to the permeability of the tape; see H. N. Bertram and D. A. Lindholm, "Dependence of Reproducing Gap Null on Medium Permeability and Spacing," *IEEE Trans. Magnetics*, vol. MAG-18, pp. 893–897 (1982 May).