THE PHILIPS-MILLER SYSTEM OF SOUND RECORDING

By R. VERMEULEN.

Contents. On the ordinary disc sound is recorded and reproduced mechanically; in the photographic method of sound recording, both recording and reproduction are carried out by optical means. Mechanical reproduction on the one hand and optical recording on the other hand possess certain inherent disadvantages. The Philips-Miller system of sound-recording, whose principles are discussed in this article, avoids these disadvantages, in that the sound-track is recorded on the film by mechanical means and is then optically reproduced.

The art of recording music and speech with high fidelity — it is impossible to conceive of modern life existing without it — has been employed in a host of directions. It is the medium for bringing music into the homes of all, it has proved useful in the teaching of languages, it is employed for producing ethnographical and cultural documents and records, in ordinary office work (in the form of the dictaphone), and on a more magnificient scale for producing sound-films and for broadcasting purposes. Particulary the latter two fields of application have made very specific demands, not always easy to fulfil, on the methods employed for recording sound.

In the oldest form of sound-recording apparatus, the Edison phonograph, the recorded sound-track was inscribed on a wax cylinder. Where no copies of the sound-track are required and the quality of the sound does not have to satisfy special requirements, as for instance in the dictaphone, this earliest method of recording is still employed to the present day. In later methods a magnetisable steel wire, a wax disc, or a strip of film or paper chart were, or are still being, used for recording a sound-track.

For reproducing music in the home, the classical method of sound-recording continues to be employed, viz, the gramophone disc. It is evident therefore that in making the first sound-films the gramophone disc was also selected to carry the recorded sound. Certain difficulties were, however, soon found to be inherent in sound-tracks on discs, as for instance the difficulty of synchronising the sound after "cutting" and "splicing" the film, and the frequent changing of the discs which was necessary owing to their short playing time, etc. For this and other reasons another method of recording sound was adopted in sound-film work, viz, the production of a sound-track on the film strip itself. The sound-track was inscribed by optical means, the blackening produced by a narrow beam of light on the photographic surface being made to vary in synchronism with the sound vibrations either in dimensions (variable width) or in intensity (variable density) (see figs. 5 and 6). Various inconveniences inherent in this method, such as the time lost for developing the film, a weakening of the higher notes, etc., were temporarily tolerated or complicated means were evolved for remedying them.

In the Philips Laboratory a new method for recording sound has been evolved in the last few years, which is based on a principle proposed by J. A. Miller. A description of this Philips-Miller system, which has now reached a high stage of perfection, is given below. In this article it is proposed to describe in the main the principle employed and to compare this new method with those in use hitherto. The technical development of the basic principle of the Philips-Miller system introduced a number of special problems, the solution of which will be discussed in a series of articles in this Review.

1) "Splicing" is the operation of joining together a number of pieces of film in the required order to produce the final sound film or news reel.

Basic Principle of the Philips-Miller Method

In the Philips-Miller method as in the photographic sound-film processes a sound-track is recorded on a strip of film. However, this is not done by optical means as hitherto but by mechanical means. The film material, the "Philimil" tape, consists of a celluloid base, which in place of the usual photographic emulsion is coated with an ordinary translucent layer of gelatine about 60 μ in thickness, on which a very thin opaque surface layer about 3 μ in thickness is affixed. Perpendicular to the tape, a cutter or stylus shaped like an obtuse wedge as shown in *fig. 1* moves in synchronism with the sound vibrations to be recorded. This cutter removes a shaving from the gelatine layer which is displaced below it at a uniform speed.

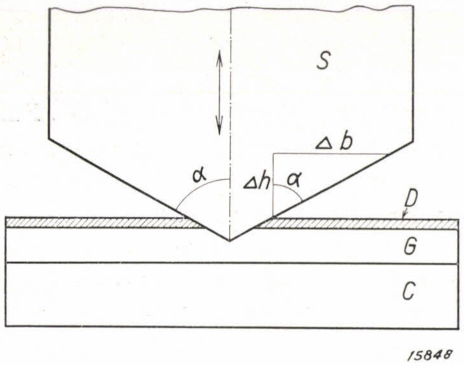

Fig. 1. Section through the wedge-shaped cutter S and the "Philimil" tape. The latter consists of a celluloid base C, a transparent layer of gelatine G and a very thin opaque coating D. The cutter shaves a groove from the tape which is moved under the cutter. The coating D thus being removed along this groove, a transparent track on an opaque background is obtained. By making the cutter in the form of an obtuse wedge, small elevations and depressions Δh of the cutter produce marked changes in width $2\Delta b$ of the inscribed track; with a semi-apical angle of the wedge α the "magnification" is $2 \tan \alpha$. In practice α is made 87 deg, hence $2 \tan \alpha$ = about 40.

If the cutter remains stationary, it cuts a groove of uniform width $2b$ in the film below it. Along this groove the thin top coating (and a part of the gelatine layer) is removed, so that a transparent trace is obtained on an opaque background. If the cutter is now brought deeper into the film by a distance Δh, the groove cut will become wider by a small amount $2\Delta b$ (cf. *fig. 2*) and if α is half the apical angle of the wedge (fig. 1) the relationship

$$2 \Delta b = \Delta h \cdot 2 \tan \alpha$$

will apply. At $\alpha = 90$ deg, $\tan \alpha$ will be infinity; it is thus seen that if α is nearly 90 deg a slight displacement Δh of the cutter will produce a marked alteration $2\Delta b$ in the width of the recorded trace. With 87 deg, the angle of the wedge used in practise, the "magnification" obtained will be $2\Delta b/\Delta h = 2 \tan 87$ *deg*, i.e. about 40.

Now if the cutter moves up and down in synchronism with the sound vibrations to be recorded (perpendicular to the tape), a transparent track on an opaque background will be produced on the moving tape whose width will vary in synchronism with the sound vibrations *(fig. 3)*. To obtain a maximum width of trace of $2b = 2$ mm, as commonly used in sound-film recording practice, the displacement of the cutter need only have a double amplitude Δh of $2000/40 = 50\ \mu$. The principal characteristic of the whole method is this small magnitude required for the cutter amplitude.

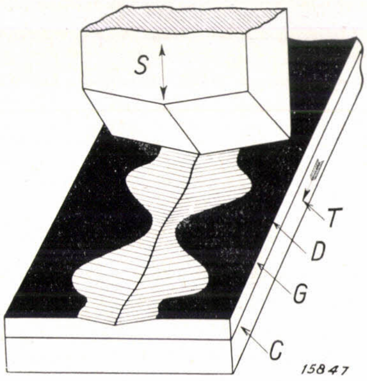

Fig. 3. The cutter S moves up and down in synchronism with the sound vibrations to be recorded (perpendicular to the plane of the tape). D, G and C represent the same as in fig. 1. A transparent sound-track on an opaque background is produced on the "Philimil" tape which moves under the cutter in the direction T.

The recorded sound is reproduced by the usual method employed in optical sound-film technology. The film carrying the sound-track is moved between a photo-electric cell and a small, brightly

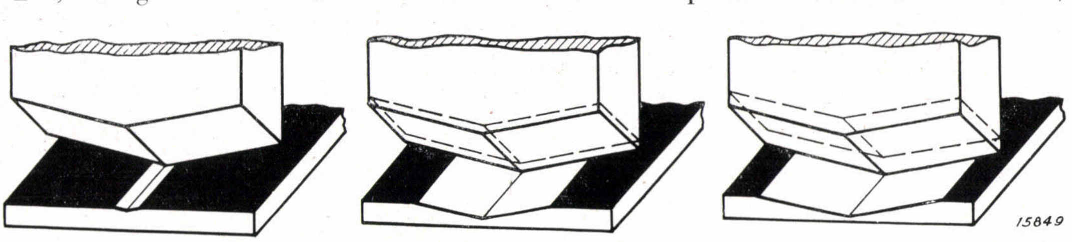

Fig. 2. The width of the track inscribed in the tape for three different positions of the cutter.

illuminated slit (transversal to the direction of motion of the film). The intensity of the light falling on the photo-electric cell thus varies with the variable width of the sound-track, and the resulting current fluctuations in the photo-electric cell are amplified and passed to a loudspeaker.

The Philips-Miller system is thus a combination of a mechanical recording method with an optical method of reproduction. This unique association offers distinct advantages over the methods hitherto in use, as will be evident from the discussion below.

Mechanical Sound Recording and Reproduction on Discs

Sound is recorded on the gramophone disc by mechanical means: an oscillating cutter (scribing stylus) cuts an undulating groove in a wax disc *(fig. 4)*. Reproduction is also performed mechanically, the gramophone needle

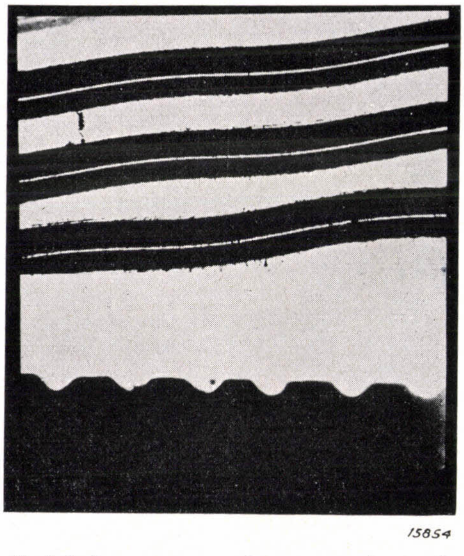

Fig. 4. Undulating grooves of a gramophone disc. View from above and in section.

(reproducing stylus) being made to follow the undulation of the groove. The disc is manifolded with the aid of a mould produced by electro-deposition. This process is very suitable for producing large numbers of a record and will therefore not be easily superseded by any other process. Yet it possesses certain general disadvantages in in addition to those already referred to and which are particularly undesirable for sound-film work, viz, the short playing time of a disc and the difficulty of excising part of the sound-track. As a result of mechanical playing back the disc is subject to considerable wear; even if the needle is changed each time the disc is played, the quality of reproduction is still noticeably reduced already after playing the disc 20 times. Moreover, the resistance to motion produced by the needle on the revolution of the disc depends on the intensity of modulation in the sound-groove, so that in a loud passage (particularly of pianoforte music) the disc may be retarded, with the production of the well-known undesirable booming effect [2]).

Above all the method of reproduction introduces an unavoidable falling-off in the higher notes. The wear and resistance to motion of the disc are due to the needle on travelling through the groove sustaining considerable accelerations, i.e. great forces, at all highly curved points. In fact with too great a curvature in the groove the needle may even stick or break down the walls of the groove. It follows, therefore, that the curvature of the groove must not exceed a certain value (as may be readily seen, the radius of curvature must not become smaller than the width of the groove). The groove has an undulating form expressed by the equation $A \sin \omega x$, where A is the amplitude, and ω the frequency of the recorded sound; the maximum curvature and hence also the force is then proportional to $\omega^2 A$. It would, therefore, if A were constant, assume high values at the high frequencies. On prescribing that the forces must for the high frequencies remain the same as for the low ones, provision must be made in sound-recording such that the (fully-modulated) amplitude A diminishes in proportion to $1/\omega^2$. This would, however, result in such small amplitudes at the higher frequencies, that they would become indistinguishable from the ever-present small surface inequalities of the material, with the result that the higher notes would be submerged in the ground noise (surface noise) of the disc itself. Moreover, for the lower notes the amplitudes obtained would be too great, so that the distance between the grooves would have to be made very large and the discs thus become most cumbersome (or the playing time become undesirably short). In practice, therefore, a recording method is adopted in which, at full modulation, an amplitude is recorded proportional to $1/\omega$ (instead of to $1/\omega^2$) [3]). Such a frequency characteristic is in fact also very suitable for electro-

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[2]) During recording the load on the driving motor naturally also varies according to the intensity of modulation. This fluctuation in load can be conveniently taken up here by a fly-wheel. The addition of a massive fly-wheel to a gramophone for the home would, however, not be a very satisfactory solution.

[3]) At the lowest frequencies, the amplitudes are even made independent of the frequency.

magnetic reproduction. The needle is connected with an armature or a coil which moves in a magnetic field. The voltage produced by displacement of the armature, which latter for instance may be represented by $A \sin \omega t$, is proportional to the velocity $\omega A \cos \omega t$ of this displacement, i.e. proportional to the product ωA of the frequency and the amplitude. Since according to the above method of recording the inscribed amplitude A of the groove is proportional to $1/\omega$, ωA remains constant, so that we obtain directly the required constant (frequency-independent) output voltage which is passed to the valve amplifier. However, with this frequency characteristic (A proportional to $1/\omega$ instead of to $1/\omega^2$), the amplitudes of the lower notes and the curvature of the groove for the higher notes would still become too great, so that at both ends of the frequency range the amplitudes must be reduced (see footnote [3]). This loss can be compensated at the lower frequencies by selecting a suitable characteristic for the valve amplifier, but at the higher frequencies such compensation would at the same time result in a more marked ground noise.

All these disadvantages; wear, retardation of the disc, and degeneration of the high frequencies, are as we see only due to mechanical reproduction and not to mechanical registration.

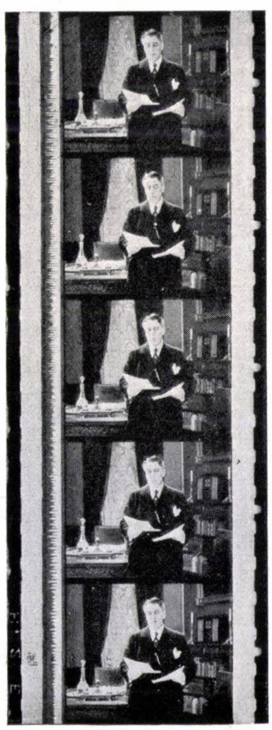

Fig. 5 Fig. 6

Fig. 5. Sound-film strip with variable-density sound-track. The sound-track is produced by illuminating the film through a slit situated transverse to the direction of motion of the film, the intensity of illumination (or the width of the slit) being varied by the sound vibrations.

Fig. 6. Sound-film strip with variable-width sound-track. This sound-track is produced by varying the length of the illuminated slit in synchronism with the sound vibrations, see fig. 7.

Optical Sound Recording and Reproduction from Sound-Film Tracks

Optical registration of the sound-track on a film strip represented a marked advance in sound-film technology. The playing time was now made much longer, being the same as for the picture itself. Synchronising vision and sound, and film cutting and splicing were also much simplified. Wear resulting from (optical) reproduction no longer occurred, nor a fluctuating load placed on the motor which pulls the film through the reproduction machine. Optical reproduction thus offered a very satisfactory solution of the problem. Also manifolding is very simple since as many copies as required can be obtained by photographic means.

Certain drawbacks of the optical method are, however, inherent in the method of recording the sound track. The film is exposed by an illuminated slit of varying intensity (variable-density record, *fig. 5*) or of varying length (variable-width record, *figs. 6* and *7*). The illuminated slit always has a definite width, e.g. 25 μ. With a film speed of

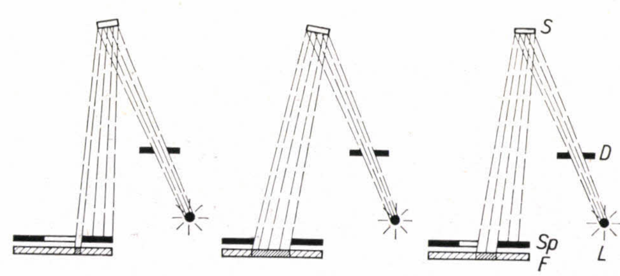

Fig. 7. Arrangement for the photographic recording of a variable-width sound-track. From the light emitted from the constant light source L a beam is passing through the diaphragm D. The mirror S mounted on a sensitive oscillograph throws the beam of light on to the slit Sp, under which the film F is moved (perpendicular to the plane of the paper). When the mirror S commences to swing under the action of the sound to be recorded, the sharply-focussed beam of light oscillates to and fro over the slit Sp and produces a blackened band of varying width on the film (see fig. 6). The path of the rays is shown for three different positions of the mirror.

50 cm per sec $= 20000 \cdot 25\ \mu$ per sec, each part of the film is therefore in front of the slit for a period of 1/20000 sec. With a vibration of 5000-

cycle frequency, the brightness of the slit with a variable-density record or the length of the slit with a variable-width record varies quite considerably already in this period of time, so that the modulation recorded on the film decreases in intensity in favour of an increasing uniform blackening over the whole width (or, with the variable-width method: part of the width) of the film.

The finite width of the slit thus results in a certain degeneration in reproduction of the high notes [4]). The same effect is also produced by the unavoidable grain and halation due to dispersion and reflexion of light (cf. *fig. 8*) in the photographic material; the grains and the lack of definition at the edges of the sound-track produce a murmur on reproduction, which again affects especially the high notes.

In fact the use of photographic material is not very satisfactory. After the sound has been recorded it is necessary to wait until the film has been developed, which frequently results in much inconvenience owing to loss of time (it is usually necessary to wait until the next day). It is true developing can be accelerated but speed is only obtained at the expense of quality. The blackening produced on the film must depend in a definite way on the exposure in order to obtain undistorted reproduction [5]), and to satisfy this requirement it is essential to exercise considerable care in developing.

We thus see that in the optical method the disadvantages (loss of time and also deterioration of the high frequencies) are due mainly to optical recording on the photographic material, and not to the method of optical reproduction.

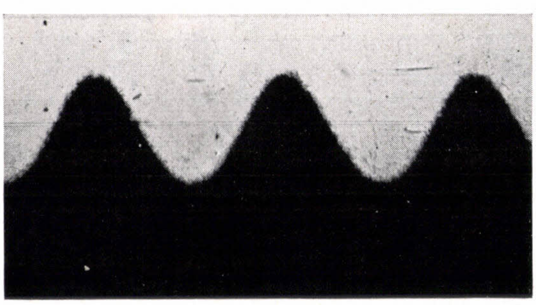

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Fig. 8. Microphotograph of a variable-width record of a 1000-cycle note. Owing to the grain and dispersion of light in the emulsion the track is not wholly sharp. Magnification approx. 50 times.

Mechanical Sound Recording on a Tape

In the Philips-Miller method the disadvantages of mechanical reproduction as well as those of photographic recording are avoided, since reproduction is effected by optical means and registration on the film by mechanical means. Already before Miller, various other methods had been evolved to the same end, but all proved unsuccessful as the mechanical recording of sound on the film had to face insuperable obstacles. Some details of these difficulties will be discussed here.

In optical reproduction of the sound-track, the fluctuations in light, i.e. the modulation of the track width on the "Philimil" tape are converted directly into voltage fluctuations. In contrast to the method of reproduction with discs where, in agreement with the insertion of the electromagnetic system, the recorded amplitude was made to diminish with increasing frequency, in the optical method of reproduction the recorded amplitude is made independent of the frequency, in order to obtain an output voltage independent of frequency. *Fig. 9* shows in a striking manner the difference in sound-recording with both these types of amplitude-frequency relationship. One and the same sound vibration has been recorded on the

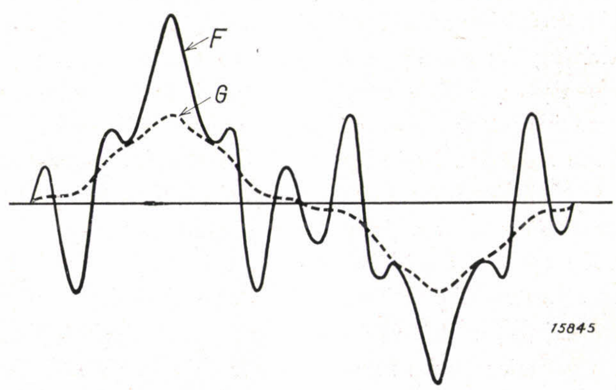

Fig. 9. Records of exactly the same sound vibrations using two different amplitude-frequency relationships. For optical reproduction (film) the amplitude must be independent of the frequency with a given intensity of sound (continuous sound curve *F*). For mechanical reproduction (disc), the amplitude must be inversely proportional to the frequency (dotted sound curve *G*). It is seen that in the first case (continuous sound curve) the higher frequencies are much more pronounced in the sound-track.

[4]) This effect of course is also obtained in the (optical) method of reproduction, but if it only occurs during reproduction it is not yet so troublesome as when it occurs twice, viz, during both recording and reproduction.

[5]) This condition is also due to the finite width of the slit. With an infinitely narrow slit, the law of blackening can have any arbitrary from in the variable-width method where the length of the illuminated slit is varied, but not so with a finite slit, owing to the half shadows produced at the edges (in variable-density recording where the intensity of blackening is varied, still more severe requirements must be met as regards accurate maintenance of the prescribed relationship between blackening and the incident amount of light).

basis of each frequency relationship. It is seen that on the film (amplitude for optical reproduction being independent of the frequency) the high frequencies are much more distinctly recorded than on the disc (where the amplitude diminishes with the frequency), and are hence also situated higher above the interference level. The normal width of the sound-track on the sound-film is 2 mm. The sound-recording machine must therefore record an amplitude of 1 mm.

How must a system be designed for mechanically recording sound? Let the stylus or cutter be attached to a spring-controlled armature, which for instance may be driven electromagnetically by the amplified microphone currents. The mechanism can be visualised as a mechanical oscillator of mass m (armature with cutter), a directional force c (spring control) and a certain damping constant r. If the system is set in motion by a force $k \sin \omega t$, it will oscillate with an amplitude:

$$A = \frac{k}{\sqrt{(c - m\,\omega^2)^2 + (r\,\omega)^2}} \quad \ldots \quad (1)$$

This equation can be reduced to the form:

$$\frac{A}{k/c} = \frac{1}{\sqrt{[1 - (\omega/\omega_0)^2]^2 + \delta^2\,(\omega/\omega_0)^2}} \ldots \quad (1a)$$

where $\omega_0 = \sqrt{c/m}$ is 2π times the natural frequency of the undamped system and $\delta = r/\sqrt{mc}$ is the only parameter contained in this expression. *Fig. 10* shows $A/(k/c)$ plotted against ω/ω_0 for various values δ of the parameter. If the damping is not too high ($\delta < 1$), resonance is obtained in the neighbourhood of $\omega/\omega_0 = 1$, i.e. when the driving frequency ω is close to the natural frequency ω_0. The curves show that it is essential to remain below the resonance frequency if an amplitude sufficiently independent of the frequency is to be realised, or alternatively, since the frequency range of sound registration is fixed (up to approx. 8000 cycles) the driving system (sound recorder) must be so dimensioned that its natural frequency $\omega_0 = \sqrt{c/m}$ lies within the range of the highest frequencies to be recorded. For this purpose it is evident that the controlling force c must be made large and the mass m small. The diminution possible in the mass of the armature is, however, limited by the dimensions which it must have in order to obtain the requisite driving force to overcome the resistance of the tape and inertia of the cutter. We are therefore constrained to make the directional force (of the spring) c of the system very large, but this in its turn results in the amplitude A, with which the system responds to one and the same force k, becoming undesirably small; this follows from equation (1). This drawback cannot be remedied, either, by increasing k arbitrarily, since this will lead to an increase in the stress on the material and soon exceed the permissible limiting load.

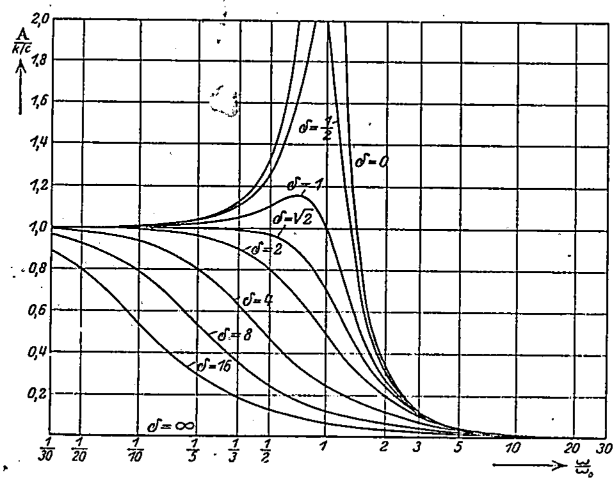

Fig. 10. Resonance curves of an oscillating system (spring controlling force c, mass m, damping r) set in motion by a force $k \sin \omega t$. The frequency ratio ω/ω_0 ($\omega_0 = 2\pi$ times natural frequency) is plotted along the abscissa (which for convenience' sake is divided logarithmically), and the ratio of the amplitudes $A/(k/c)$ (A = amplitude with which the system responds to excitation) along the ordinate. The resonance curve if plotted in these dimensionless variables is completely determined by the similarly dimensionless parameter $\lambda = r/\sqrt{mc}$. In working out the dimensions of the sound recorder the form of the resonance curve is the primary factor; δ ought to be made equal to about unity. In addition A/k should be as large as possible. (Reproduced from B. D. H. Tellegen, Arch. Elektrotechn. 22, 62, 129.)

The conclusion must therefore be drawn that a high natural frequency and a considerable amplitude independent of the frequency cannot be realised simultaneously [6]). Miller provides a way out of the difficulty: By giving the cutter the shape of an obtuse wedge (fig. 1) the sound-track is recorded with a large amplitude (= half-width of track = 1 mm at complete modulation), while the amplitude of the mechanical oscillating system serving as sound recorder need only be comparatively small, viz, a maximum of 25 μ. These values can just be attained by most careful construction. In a following article the whole problem involved here will be discussed in greater detail. *Fig. 11* gives the frequency characteristic of the sound recorder which has been attained at present.

[6]) In the mechanical recording of sound on discs, conditions are much simpler in this respect as only at the lower frequencies is a pronounced amplitude required, but with the high frequencies a lower amplitude is needed; this kind of frequency characteristic is readily to be obtained from the ordinary form of resonance curves, see fig. 10.

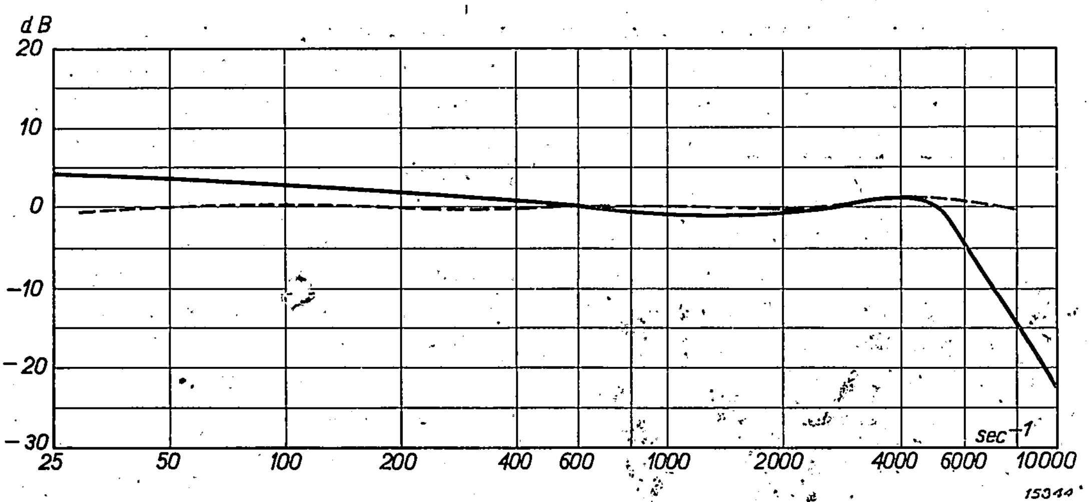

Fig. 11. Characteristic of the sound recorder (continuous curve) as at present constructed. The sound frequencies in cycles are plotted logarithmically along the abscissa and the amplitude differences in decibels along the ordinate. (A difference of m decibels between two amplitudes A_1 and A_2 ($A_1 > A_2$) signifies that the squares of the amplitudes A_1^2 and A_2^2 are in a ratio of $10^{0.1m} : 1$). It is seen that the amplitude between 20 and 6000 cycles is practically independent of the frequency. The dotted line gives the characteristic of the whole recording and reproducing apparatus; by suitably designing the amplifier the characteristic is still further improved with respect to the continuous line; the differences in the range between 20 and 8000 cycles do not now exceed 2 decibels, which is hardly to be heard. Reproduction is thus free from (linear) distortion.

The high magnification with the wedge-shaped cutter called for the solution of a number of practical problems. The slightest change in the distance between the cutter and the tape, as a result for instance of a slight eccentricity of the roller carrying the tape or the presence of a particle of dust between the roller and tape, or a slight variation in the thickness of the tape, is able to cause immediately an audible distortion of the sound-track. The recording apparatus must therefore be constructed with the greatest precision, while in the manufacture of the tape every care must be taken to obtain maximum uniformity and purity of the material. This latter precaution is also necessary in order to prevent the very heavily-stressed cutter becoming damaged by particles of dust or traces of impurities in the gelatine layer.

It is also most essential to have an absolutely uniform motion of the tape. The resistance applied by the tape to the cutter, however, varies with the width of track from 0 to 2 kg, this rendering the uniform motion very difficult to be obtained. The fluctuation in load cannot be taken up by the perforation taken over from the picture film and by the driving sprocket wheel, without producing undesirable vibrations in the tape motion. A new driving method has brought the remedy here.

The recorded tape can be copied photographically in the same way as an ordinary variable-density or variable-width sound-film, but as the sound-track possesses a modulation not only in its width but also in its density, it acts on a beam of light passing through it as if it were a prism. The fluctuations in the light resulting herefrom do not cause interference, and in any case can be rendered innocuous by simple means.

Characteristics and Applications of the Philips-Miller System

The sound-track on the "Philimil" tape has the same desirable characteristics as the ordinary film: A longer playing time (30 tot 60 minutes), the possibility of cutting and splicing, and the production of copies photographically. In addition all disadvantages of the photographic material have been avoided. All operations with the film strip can now be carried out in daylight. The sound-track is more sharply recorded since no granulation and dispersion of light in the photographic emulsion occur here, see *fig. 12.* Moreover, owing to the almost complete absence of granulation in the material the ground noise has been considerably reduced. High frequencies are recorded with more fidelity; the cutter can be made so sharp that it does not alter the frequency characteristics, as was the case in the optical method of recording by the width of the light-slit.

The most important and most striking advantage offered by this method is that the sound-track can be reproduced immediately the recording process has been completed (e.g. after 1/5 of a second). This property is of the greatest impor-

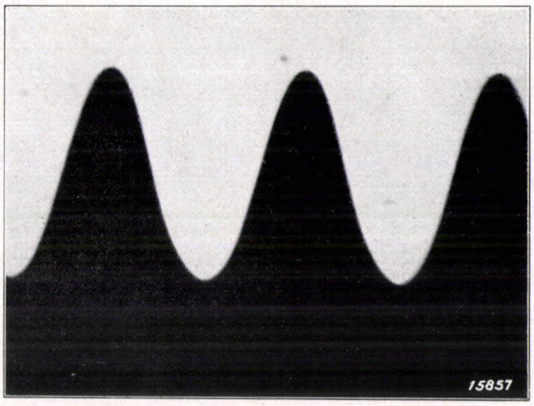

Fig. 12. Microphotograph of the sound-track of a 1000-cycle note on the "Philimil" tape, with the same magnification as in fig. 8. The coating is devoid of all grains and the edges of the sound-track are sharply defined. The ground noise is therefore much reduced.

tance and value when recording sound-films. The producer has now no longer to wait for the development of the light-sensitive film in order to decide whether the sound record conforms with his requirements. After each scene has been recorded he can listen in to the playback of the sound-track immediately and decide on the spot of the sound-track for documentary and other repeated.

For broadcasting purposes also, the immediate reproducibility of the sound-track is of the greatest utility. The exchange of programmes between stations, the postponement of the transmission of current items of news (races, speeches, etc.) to a more suitable time of the day, the production of radio plays, all these are much facilitated by the Philips-Miller system, while the tonal quality exceeds that obtainable with the wax disc. The high fidelity of reproduction also offers a method of copying sound-records which in certain circumstances may be very convenient, viz, by making a new record of the reproduced sound track on a second "Philimil" tape. This "mechanical" copying can be carried out at the same time as reproduction, so that a direct duplicate can be obtained of the sound-track for documentary and other purposes.

THE V.R. 18 TRANSMITTING AND RECEIVING EQUIPMENT

By C. ROMEYN.

Introduction

With the progressing development of commercial flying, the need for some means of intercommunication between an aircraft in flight and the airport very soon became apparent, and the first passenger and commercial airplanes, although still very small, were already equipped with wireless apparatus. With the steady and radical improvements in technical methods and apparatus during the last ten years both flying and wireless technology have made rapid strides. The importance of wireless intercommunication during flight has progressively increased and at the present day it is impossible to conceive of a passenger or commercial aircraft being without wireless apparatus. Reports of weather conditions along the aircraft route, landing instructions, direction-finding signals, etc., have become indispensable to the pilot.

It is the task of the wireless industry to provide suitable apparatus capable of meeting the special requirements for use in modern aircraft. That an aircraft radio equipment in many respects must differ fundamentally from a permanent and stationary ground equipment is obvious. In the present article the V. R. 18 aircraft transmitting-receiving equipment designed by Philips is described. This equipment has been specially evolved to meet the various requirements for use aboard aircraft, yet in its design attention has, moreover, been given to certain specialised needs