B.B.C.-MARCONI RIBBON MICROPHONE

PART 1. TECHNICAL DESCRIPTION.

Description.

This microphone was developed by the Research Department of the B.B.C. and possesses many unique qualities which result in an almost ideal frequency response characteristic. A brief summary of the earlier experimental developments which led up to it is given in the footnote.

The microphone consists essentially, see Figure 1, of a thin corrugated ribbon of "hard aluminium" approximately $2\frac{1}{2}''$ long $\frac{1}{4}''$ wide and $.0002''$ thick suspended in the gap formed by the specially shaped soft steel pole pieces of a large cobalt steel permanent magnet. The field in the gap is parallel to the surface of the strip and at right-angles to its length and is sensibly uniform. The ribbon is held at either end in non-magnetic supports and is only lightly tensioned. Its natural frequency occurs in the region of 20 c/s and the movement is heavily damped by the magnetic field, which is of the order of 1,600 gauss. Movement of the ribbon in response to the sound, in a direction normal to its face, gives rise to current along its length. The resistance of the ribbon is only about 0.15 ohm and a mu-metal transformer, forming part of the microphone assembly, is provided in order to step-up the output impedance to approximately 300 ohms.

Two silk lined non-magnetic gauze shields are fitted, one enclosing the ribbon assembly and the other, outside it, enclosing the complete magnet assembly. These protect the movement from dust and also from air currents which might give rise to heavy L.F. surges. The upper part of the microphone unit, containing the output transformer screened in a mu-metal box, is enclosed in a non-magnetic sheet metal casing.

A microphone differing from the usual moving-coil type, in that the whole moving element in the magnetic field is itself a conductor, was first suggested by Reimganum in the year 1910, and the first patent was taken out in 1913. It was developed in a practical form by Gerlach and Schottky in 1924. They enclosed one side of the moving conductor or ribbon so that only one side was exposed to the incident sound, and the instrument operated as a pressure microphone, like condenser and moving-coil microphones. The frequency characteristic depended largely on the method of shielding one side of the ribbon, and two or more interconnected resonating chambers were used in an attempt to improve the frequency response. Recently a microphone, in which a long narrow tube filled with tufts of felt was used for terminating the enclosure at the back of the ribbon, has been described by H. F. Olson, and a good frequency characteristic is claimed for it. But pressure ribbon microphones do not possess the unique properties of the velocity type and offer little advantage over other types of pressure microphones already in general use. Sykes seems to have been the first to utilise both sides of the ribbon freely exposed to the air, but in the design adopted by him no steps were taken to counteract the loss at the higher frequencies which, as explained in the text, is unavoidable with a simple velocity type of microphone. Reference to the ribbon microphone marketed by the R.C.A. is made in a later footnote.

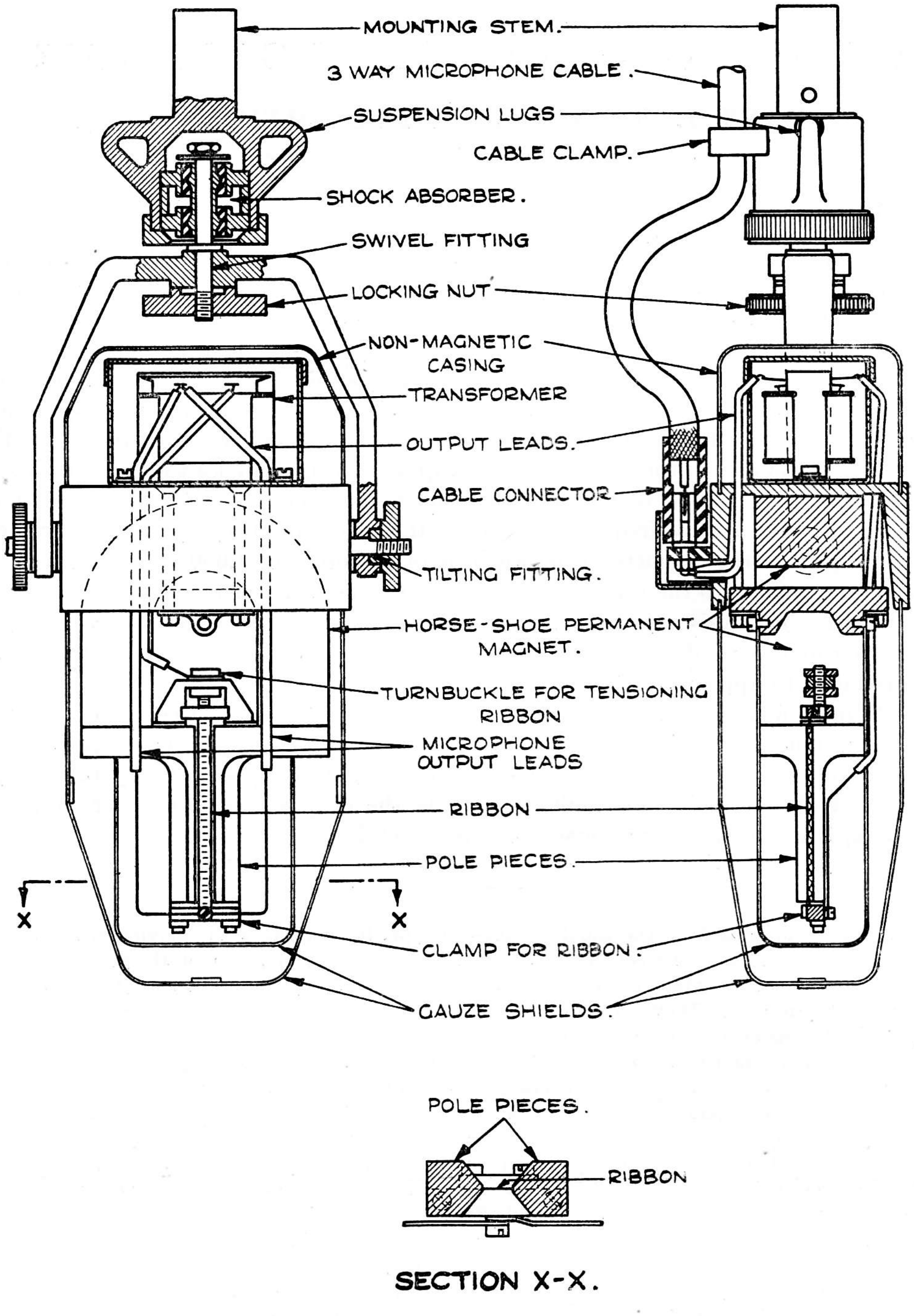

Fig. 1. Construction of Ribbon Microphone.

Description (*contd.*)

The microphone is carried in a gimbal mounting fitted with a shock absorbing attachment provided both with suspension lugs and with an adaptor that fits into any of the standard telescopic studio stands in place of the usual ring adaptor. It can thus either be mounted on such a stand with the ribbon on the top, or suspended by means of the shock absorbing thongs provided, with the ribbon at the bottom. Provision is made for inclining the microphone with respect to either the vertical axis or to the horizontal axis, and for locking it in position when suitably set.

The connections to the microphone are made by means of a standard two-conductor shielded cable, via a special 3-pin adaptor. The output pins are closely spaced, and are connected to the secondary of the transformer. The earth pin is the one displaced slightly to the right and it is connected to the casing of the microphone. The earthed shield should be connected via the adaptor to this pin. The primary of the transformer is connected directly to the two ends of the ribbon, the connection to its outer end being duplicated in order to reduce the resistance in the circuit.

The output level from the microphone itself is −74 db., zero level being one volt output for a pressure wave of one dyne per square centimetre. This is 4 db. below that of the S.T. & C. moving-coil microphone with its associated 3/1 step-up transformer.

Operation

The action of the microphone is not the same over the whole of the frequency band. Up to about 4,500 c/s it operates as a "velocity" microphone, above this frequency and up to about 9,000 c/s it operates as a "pressure" microphone, while above 9,000 c/s it functions on the "velocity" principle again.

Over the lower part of the frequency band the sound wave exerts pressure on both sides of the ribbon, reaching the back by diffraction round the pole pieces. The pressure on the back is slightly out of phase with that on the front, due to the difference in length between the paths travelled by the sound wave from the source, and the response of the microphone is proportional, not to the actual pressure of the sound, but to the resultant of the pressure exerted on both sides of the ribbon. This is actually proportional to the pressure gradient of the sound wave, which is mathematically identical with the particle velocity of the sound, whence the description "velocity" microphone. Since the particle velocity increases with frequency, it might be expected that the response of the microphone would show the same tendency, but this is counteracted by a tendency, due to the mass of the ribbon, for the response to fall as the frequency increases. In practice the response of the microphone is substantially uniform over the part of the frequency band under consideration. When, however, the path difference exceeds one half of the wavelength of the incident sound wave, the velocity principle breaks down and the efficiency falls rapidly. The frequency at which this fall in the frequency characteristic commences is determined by the cross-sectional dimension of the pole pieces which fixes the difference between the length of the paths from the source of the sound to the front and back of the ribbon respectively.

In this model this critical frequency occurs at about 4,500 c/s, but the drop in the frequency response above the critical point is effectively counteracted by shaping the pole pieces to provide a resonant cavity on each side of the ribbon. These cavities are broadly resonant over a large part of the range from 4,000 to 9,000 c/s. Over this range of frequencies,

Operation (*contd.*)

therefore, the microphone behaves as if it were a double-sided pressure microphone mounted in a small baffle. At frequencies above 9,000 c/s, the velocity principle again comes into play, since the high frequency sound waves are able to pass between the small air gap between the pole pieces and the ribbon, producing a pressure difference between front and back, and, in theory, a new half wave condition at about 20,000 c/s.*

The combination of the velocity and pressure effects described, gives an extremely good frequency characteristic which is uniform to $\pm\frac{1}{2}$ db. between 100 c/s and 6,000 c/s, -2 db. at 7,000 to 8,000 c/s and -3 db. at 9,000 c/s, the present limit of accurate measurement. There is however good reason to believe that the frequency response is well maintained up to at least 16,000 c/s. Below 100 c/s there is a rise in response with decreasing frequency, with a maximum at 20 c/s, amounting to $+4$ db. at 50 c/s. Correction for this, and for the slight loss above 7,000 c/s is applied in the "A" amplifier.

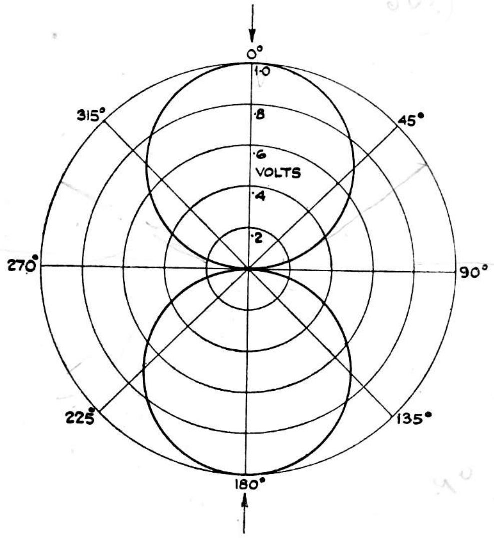

Fig. 2. Polar Diagram of Ribbon Microphone. (Approximately the same for all Frequencies.)

For a sound wave incident at any angle other than axial, the effective path difference between front and back is decreased, and therefore so also is the response. At 90° to the axial direction the microphone output is zero. The polar diagram at all frequencies is of the form $\mathbf{r = a \cos \theta}$, that is to say, as shown in figure 2, it is like a figure of eight and similar to that of a frame aerial. Unlike other microphones, therefore, this one is bi-directional, and its frequency characteristic is almost completely independent of the angle of incidence.

The response of the human ear is directly proportional to the sound pressure and is a function of distance only, but the complete mathematical expression for the response of a velocity microphone includes a term involving also a function of the distance of the sound source and its frequency. Fortunately, this term is negligible for all normal distances, but if the sound source is very close to the microphone the effect is to increase greatly the low frequency response.

The particular importance of the above unique features will be discussed in Part 2.

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* The R.C.A. ribbon microphone is a pure velocity microphone in which, as the result of special design of the pole pieces, the critical frequency occurs at about 9,000 c/s. However, the microphone is considerably less sensitive than the B.B.C. ribbon microphone and its high frequency response (above 2,000 c/s) is not so good.

Microphone Circuit

Originally it was found to be impracticable, on account of switching and "click" interference, to work ribbon microphones directly into the input of an "A" amplifier, and a single-stage amplifier, mounted in a standard MD/2 chassis was, therefore, used in order to raise the volume by 20 db. However, later investigation showed that the switching interference could be eliminated for all practicable purposes if the lines between the studios and the Control room were carefully balanced to earth and joined to unbalanced apparatus through completely screened transformers.

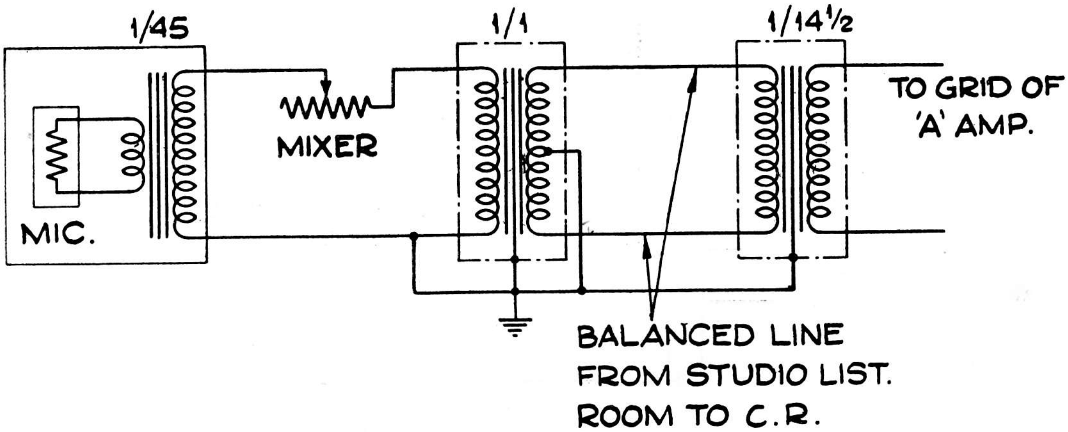


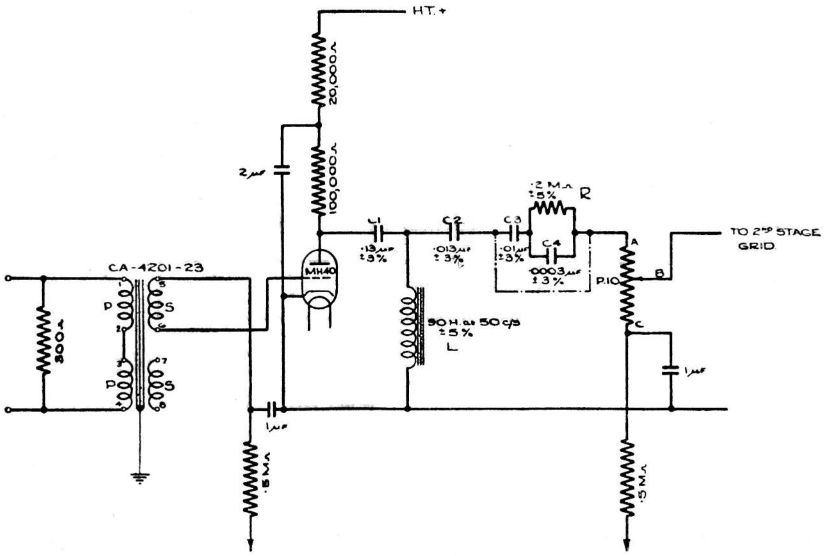
Fig. 3. Special Circuit for use with Ribbon Microphone for connecting Studio and Control Rooms.

The arrangement actually in use is shown in Figure 3 and was adopted because it involved the minimum change in the previously existing practice. The microphones are connected to the studio mixer in the normal manner and the output of the mixer is terminated by the primary of a standard repeating coil. The secondary of the repeating coil is connected to the line leading to the Control room which is constructed of "one-pair 10," or its electrical equivalent, and connected via the usual break jacks to the input of the "A" amplifier. One side of the primary of the repeating coil and the centre point of the secondary are connected to the local studio earth.

Certain changes have been made in the circuit of the "A" amplifier for use with ribbon microphones, in order to screen the amplifier completely from the input line, and to modify the frequency characteristic of the amplifier so that in conjunction with the ribbon microphone the desired overall frequency response is obtained.

Microphone Circuit (*contd.*)

The input transformer (see Figure 4) has a high step-up ratio (turns ratio 1/14·5) and very efficient screening between the primary and secondary windings. The primary has 300 ohms connected across it and is *not* normally connected to the Control room earthing system. The secondary is unloaded and the control potentiometer has been moved to the input of the second stage to replace the grid leak formerly connected there. An MH/40 valve, which was specially developed for use with ribbon microphones and has an extremely low value of internal noise, is used in the first stage.



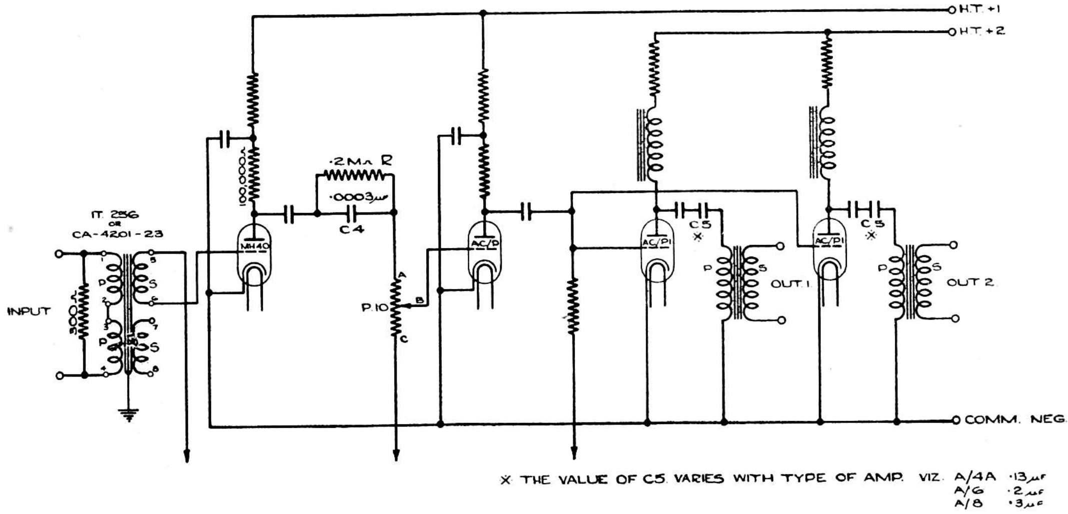
Drawing A.3989, *Issue* 1.

Fig. 4. Correction Circuits for "A" Amplifier for use with Ribbon Microphone—Grid Negative and Filament Connections omitted.

By leaving the secondary of the input transformer unloaded a gradually rising characteristic is obtained, the rise amounting to about +3 db. at 9,000 c/s and thus compensating for the slight fall at the upper frequencies in the frequency response characteristic of the microphone itself. The increase in the low frequency response of the microphone is corrected by the network consisting of the condensers C_1 and C_2 and the inductance " L," connected in the output of the first valve and giving a fairly sharp cut off in the region of 50 c/s. A similar result can be obtained by reducing the value of the coupling condenser in the output stage of the amplifier, which is the scheme adopted for modifying existing amplifiers. Actually as shown in Figure 5, an additional small condenser C_5 is connected in series with the existing condenser. By these means a sensibly flat overall frequency response characteristic is obtained for the " A " amplifier and ribbon microphone from about 50 c/s to about 10,000 c/s.

Microphone Circuit *(contd.)*

At the present time it is considered desirable somewhat to over-emphasize the upper frequencies in the transmission in order to compensate for the prevalent deficiency in response of the average listener's receiver and loudspeaker at these frequencies, and it has been found in practice that the desirable frequency characteristic is one gradually rising above 1,000 c/s to about +6 db. at 8,000 c/s. Arrangements will ultimately be made for this to be effected by the use of an equaliser in the input to the radio transmitter and up to this point each part of the transmission chain will be designed to have a uniform frequency response



Drawing A.3923, Issue 1.

Fig. 5. Correction Circuits for "A" Amplifier for use with Ribbon Microphone (Alternative Arrangement for Modification of existing Amplifier) — Grid Negative and Filament Connection Omitted.

characteristic. As a temporary measure, however, the rising characteristic desired is being obtained in the " A " amplifier. This is done by the introduction in the output of the first stage of an additional network (see Figures 4 and 5), consisting of condensers C_3 and C_4 the latter shunted by the resistance R. Where the arrangement of Figure 4 is adopted the condensers C_2 and C_3 may be combined into a single condenser of equivalent capacity.

Maintenance

From a maintenance point of view the microphone is extremely reliable and is entirely unaffected by normal atmospheric changes in temperature and humidity. It is very robust and if always handled with reasonable care the only faults liable to develop are that the ribbon may in time become slack, and that small particles of iron may collect in the gap and impede the free motion of the ribbon. Provided the shields are not disturbed, trouble due to the latter cause is very unlikely, while as regards the former, provision is made for retensioning the ribbon. If, however, the performance of a microphone is suspected for any

Maintenance (*contd.*)
reason, it should be returned to the Equipment Engineer for attention. In the ordinary course, therefore, it should be unnecessary to remove either of the protecting gauze covers. In the event, however, of this becoming necessary it should be done, not in the workshop but in a room completely free from iron filings or magnetic dust.

In regard to maintenance of the associated microphone circuits, if hum, clicks or any other interference is experienced, attention should be paid to the balance of the lines to earth.