OUTPUT CHARACTERISTICS OF MAGNETIC PICKUPS

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The pickup is an electro magnetic device for transferring mechanical vebrations into electrical potentials. The most fundamental laws underlying this piece of apparatus are Faradays laws of induction and Rowlands law of the magnetic circuit that magnetic flux equals magnetomotive force divided by the reluctance.

The magnetic pickup is superior to mechanical reproducers for several reasons. Among these are: (a) At extremely high and low frequencies, amplifier characteristics can be made to compensate for loss in amplitude in recording. (b) Filters may be used to reduce "surface noise." (c) Any volume may be generated without distortion.

A pickup and its associated amplifiers and reproducers form a system such that falling characteristics in frequency in one part is compensated by a rising characteristic in another part. Thus the result is that almost any particular band of frequencies may be eliminated or augmented.

The mechanism of a magnetic pickup is very simple. It consists of a permanent magnet between the poles of which is some type of armature separated from the poles by a short air gap. The armature is movable and connected to the needle which is forced to vibrate by following the groove on a record. In a coil which surrounds the armature an induced voltage is generated. The flux through the armature is proportional to the reluctance, which in turn is varied by changing the length of the air gap.

The three fundamental equations for such a device being:

$$\phi = \frac{\text{M.M.F}}{\text{R}}. \tag{1}$$

Where ϕ is the flux, M.M.F the magnetomotive force, and R the reluctance.

$$\frac{d\phi}{dt} = \frac{kdx}{dt}. \tag{2}$$

Where x is the distance the armature moves in the air gap, and k is a constant depending upon the units used.

$$E = \frac{d\phi}{dt} = \frac{k\,dx}{dt}. \tag{3}$$

Where E is the voltage generated.

An ideal pickup should have a rising low frequency characteristic to make up for the loss in amplitude necessary in recording low frequencies. The voltage frequency curve should have no sharp peaks indicating resonance and consequent distortion. Such a device should have a rapidly falling characteristic above 5,000 cycles to prevent surface noise or "needle scratch."

The purpose of this paper is to outline a method for measureing the output voltage of a pick up at frequencies from 50-5,000 cycles and thereby obtain a voltage frequency characteristic over the ordinary acoustic range.

The ear cannot be relied upon in determining the points of maximum signal intensity because a great many people are relatively deaf to certain frequencies as indicated by the work of J. P. Minton[1]. Another important point to be considered is the sensitiveness of such a device, that is its actual output voltage. To measure this voltage a vacuum thermocouple was first used but due to the slow action of such a device the results obtained were unsatisfactory. A vacuum tube voltemeter of the "leaky grid" type was then constructed. This instrument was then calibrated in R. M. S. volts and used to measure the actual output voltages. A set of constant frequency records, which were made in the Bell Telephone laboratories, was obtained from the Victor Company. If rotated at the stated speed the grooves of these records were designed to give a constant frequency to a sound reproducers stylus at approximately constant energy output.

Since a pickup is a complex mechancial and electrical system both the mechanical and electrical impedances are effective in determining the output characteristics of such a device. Consequently the output voltages must be measured under conditions which are the same or similar to the conditions of actual use. Figure 1 shows three methods used for measuring the output under different conditions. In addition curves were taken with only the voltemeter as load, a condition which would exist were such a device to operate directly into a vacuum tube. In practice however such devices generally operate directly into an input transformer or a volume control device.

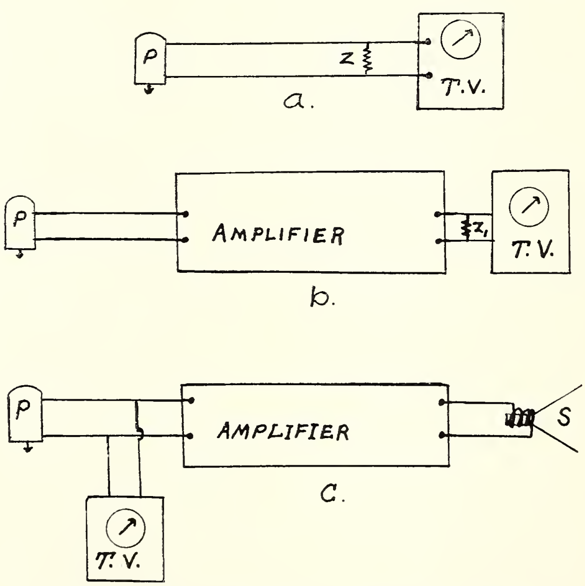

Fig. 1. Schematic diagram for tube Voltmeter connections

[1]Phys. Rev. XIX. No. 2, p. 80; 1921.

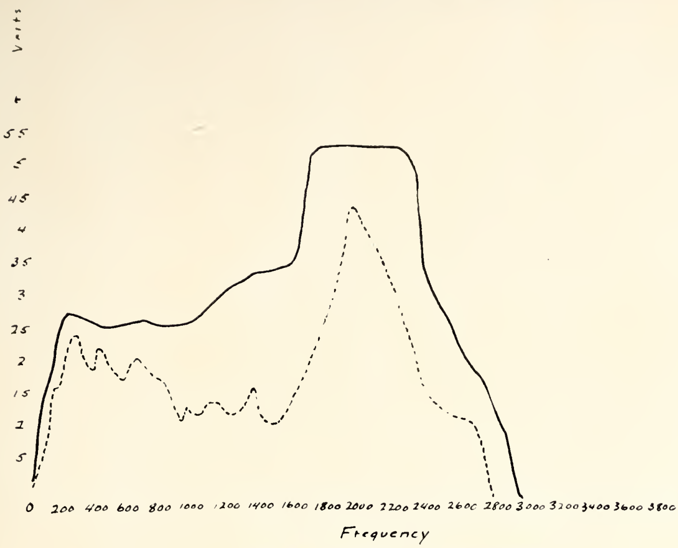

Fig. 2. The output of a poor pickup.

Figure 2 is a curve showing the output characteristics of a cheap pickup. For this curve the frequencies are plotted as abscissas against the voltages generated as ordinates. The continuous line gives the output when the device is operating directly into the proper amplifier. The broken line is the characteristic curve of the pickup with only the vacuum tube voltmeter as load. This pickup would over-emphasize the notes between 1,600 and 2,600 cycles and give practically no reponse above 3,000 cycles.

Figure 3 represents a higher quality pickup. The no load curve is very poor while the curve for proper load is excellent with the exception that the frequencies above 3,400 cycles do not register.

Figure 4 is a curve showing the characteristics of a good pickup. This pickup has a flat curve in which the lower frequencies are slightly augmented. It reproduces all frequencies up to 5,000. With a proper designed amplifier this device would give very faithful reproduction. The broken curves represent the generated voltages at loads other than the proper load. These curves show in some cases marked resonance peaks indicating distortion. It may be noticed that with the exception of the curve of figure 4 the cut-off frequencies are too low.

The accompanying curves were made by Geo. M. Urey in a study of the reasons for excessive record wear, with equipment designed and furnished by the author. Mr. Urey found by microscopic examination that the record grooves broke down at frequencies corresponding to pronounced peaks in the voltage output curve. Such peaks cause harsh metallic sound in the amplified sound output. These resonant peaks can be corrected by: (a) Mass loading in the mechanical system for low frequencies, (b) damping springs and cushions for the high frequencies, (c) matching impedances to prevent resonance and reflections in the electrical system.

Much research has been done upon pickups in the last two years and the device is at present a close competitor of the photo electric cell in sound reproduction. The problem of surface noise, however, remains to be solved.

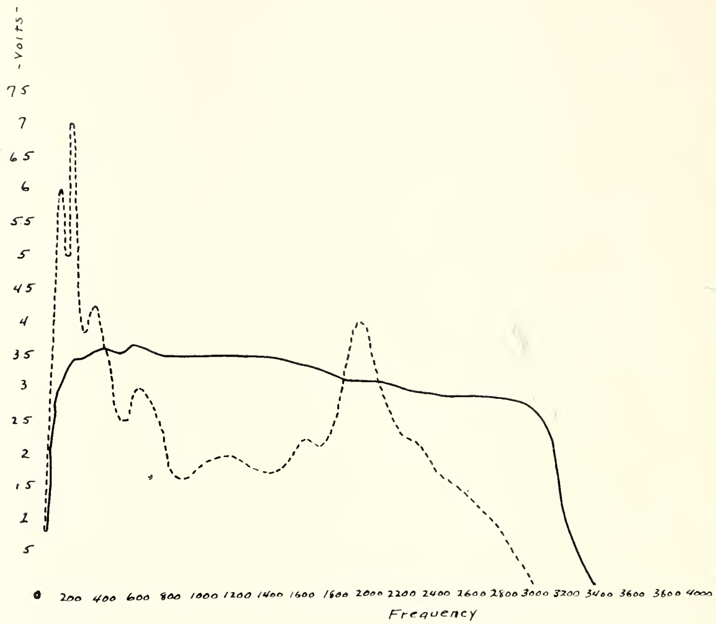

Fig. 3. The output characteristic of an average pickup.

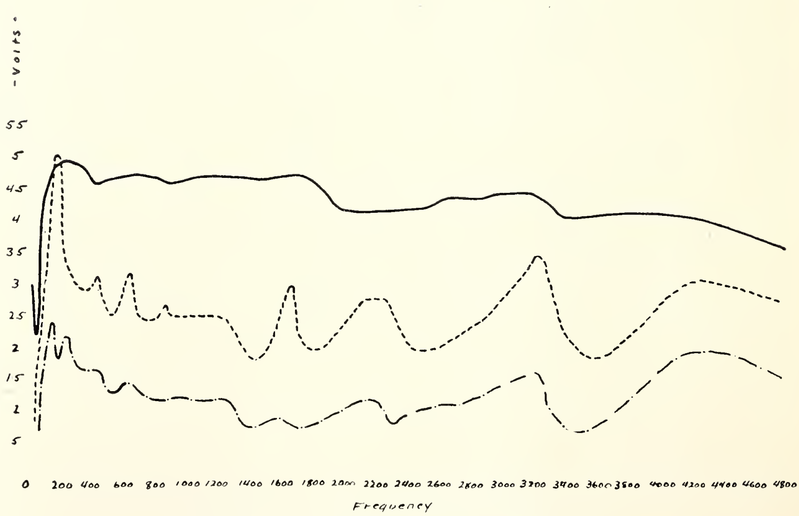

Fig. 4. The output characteristic of a good pickup.