not transmitted in monophonic systems (even if such a signal is correctly decoded in the Center Back of a quadraphonic array)[2], the use of Center-Back direction is discouraged with the SQ system. In effect, the above set of modulations defines the basic SQ matrix system.

It is shown in [1] that during reproduction the SQ-encoded signals are "decoded" into a set of four-channel signals which retain infinite interchannel separation between the front and the back channel pairs, provide 3 dB interchannel separation between the side channel pairs, and 0 dB separation between Center-Front and Center-Back signals. By using a "blend matrix" decoder or, especially a "matrix-plus-logic" decoder—the latter to be described in a companion paper—the side channel and the front-back separation can be increased to as much as 20 dB or more, resulting in a four-channel reproduction which compares very favorably with the original, discrete, four-channel master tape.

Among the important attributes of the SQ system is its full compatibility with existing stereophonic and monophonic phonographs and with all AM and FM transmission systems. This is ensured in the first instance by the complete separation of the front channels and by a favorable "folding" of back-channel signals in a stereophonic field, and by in-phase relationship of all front-channel-panned signals. In the second instance, the double helix allows the back corner signals to be transmitted in the monophonic mode with the same relative levels as the two front corner signals. This is noted from the fact that the projections of L_F and R_F in Fig. 1**a** upon the horizontal axis are equal to the diameter of the helixes. This code is the only one proposed thus far which possesses all the above characteristics.

As to practical significance of the above-mentioned attributes, it should be remembered that the capability of correctly transmitting the corner signals in the monophonic mode is requisite, as all AM and probably 90% of all FM radio listening are monophonic, and 80% of all phonographs currently available in some important markets—Europe, for example,—still are monophonic. The ability of retaining full front channel separation ensures that a symphony orchestra, for instance, spans the full space between loudspeakers in the stereo mode, and is an indispensable attribute of good stereo compatibility.

In the monophonic mode, the Center-Front (C_F) signal is transmitted at a +3 dB level, as in the case of stereo recording.[3]

OPTIMUM SIDE MODULATION AND DIAGONAL SPLITS

The basic set of SQ modulations in Fig. 1**a** does not define the set of modulations for producing Center-Left (C_L) and Center-Right (C_R) signals. These are not frequently encountered in real life recording except for reverberant energy pickup. Nevertheless, some producers have expressed a desire to place performers on the sides of the audience. By analyzing the decoder action, we have determined that for optimum results, side signals should be encoded in the form of two elliptical helixes with 2.42:1 major/minor axes ratios with the major axes coincident with the L_F and R_F signals, respectively, and sequenced to rotate oppositely with respect to each other in the manner shown in Fig. 1**b**. When playback signals corresponding to these elliptical modulations are applied to a basic SQ decoder, the decoded signals yield channel separations of 7.6 dB between the left and right pairs of channels, which is sufficient to make a side-to-side separation-enhancing logic superfluous. Encoder circuits to implement these side modulations are described later in this paper.

For the moment, it is sufficient to note that all the modulations shown in Fig. 1**b** are inscribed within the square joining the ends of the vectors L_F and R_F. They do not alone occupy more lateral or vertical modulation space than the two basic front channel signals.

It is further noted, without proof, that elliptical modulations equal in magnitude to those shown for C_L and C_R, but rotating in directions opposite to the arrowheads will decode in an SQ decoder into signal pair "splits" L'_F and R'_B and R'_F and L'_B, respectively, with a 7.6 dB channel separation relative to the signals transferred to their respective cross-diagonal pairs.[4]

ENCODING SQ RECORDS

The simplest procedure for encoding an SQ record is to prepare a suitable four-channel master tape, and to apply it to the four input terminals of an SQ encoder. The signals which appear at the two output terminals are conveyed directly, or via an encoded master tape, to a conventional stereophonic disc cutter. The producer soon learns from experience which placement of sounds in the quadraphonic master tape produces the most effective decoded program, which he can approve by auditing the decoded signals. Most of the existing SQ records have been produced in this manner. Nonetheless, with the advance of quadraphonic mastering techniques and the desire of artists and producers to introduce special effects, a number of procedural and encoder refinements have been evolved which are described in the following pages.

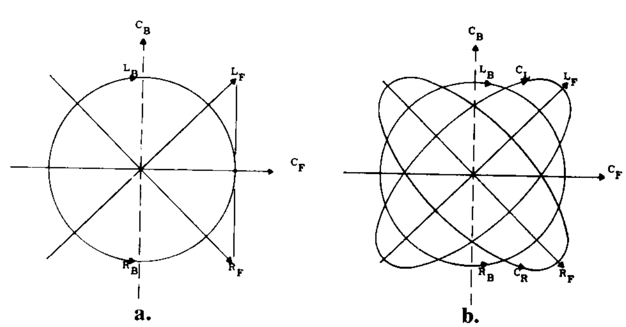

Fig. 1. SQ vectors **a.** basic modulations and **b.** complete set with optimum side modulations added.

[2] The RM matrix (see Appendix) also places the Center-Back signals in the vertical modulation mode.

[3] From time to time in the past, it has been suggested that conventional stereophonic signals should be recorded or transmitted through relative 90° phase-shift psi networks in order to prevent the 3 dB buildup. Fortunately, this procedure has never gained significant popularity, and it is hoped that it will enjoy a quiet passing. Any extraneous phase shifts introduced into a stereophonic program will adversely affect its capability to play compatibly through quadraphonic decoders.

[4] It is also noted in the Appendix that the RM system does not define a diagonal splits capability.