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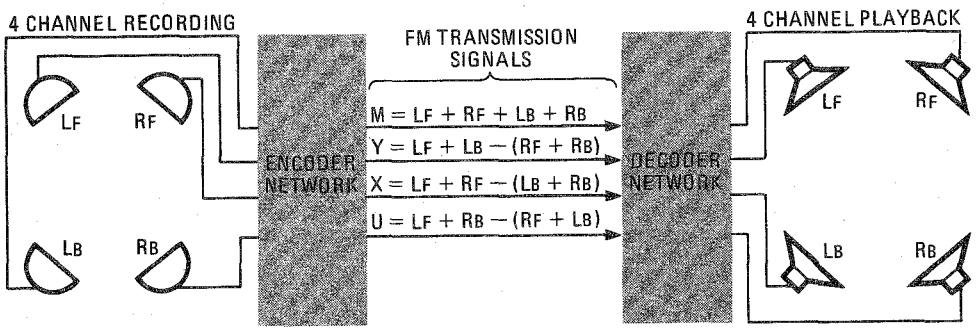

FIG. 1—DISCRETE 4-CHANNEL BROADCAST system uses four transmission channels. To maintain compatibility with existing stereo and mono receivers, the four channels are encoded at the transmitter and decoded at the receiver.

4-Channel FM

With discrete and matrixed 4-channel tape and phono formats dormant, the fight for 4-channel programmming continues on the broadcasting front.

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IT HAS BEEN SOME TIME SINCE WE DISCUSSED quadriphonic sound; indeed, superficially at least, it would seem that the audio industry and consumers alike have all but turned their backs on 4-channel sound. Very few, if any, 4-channel records are presently being released (although the number of available releases in all formats—matrix or discrete—exceeds 1000), and hi-fi component manufacturers have all but abandoned production of any quadriphonic reproducing equipment.

There is one aspect of the 4-channel scene that is very much alive—4-channel FM broadcasting. Back in March, 1972, when interest in quadriphonics was at its height, the Consumer Electronics Group of the Electronics Industry Association (EIA) voted to sponsor the organization of a National Quadriphonic Radio Committee (NQRC) whose objective was to report to the Federal Communications Commission its final technical conclusions regarding 4-channel FM sound broadcast standards. The FCC endorsed the study project and the NQRC plunged into its complex task of analyzing, evaluating and, finally, field-testing five proposed systems for discrete 4-channel FM broadcasting.

The work continued until late 1975 and, in November of that year, the final NQRC report was submitted to the FCC. Nearly two years later, on July 6, 1977, the FCC released its formal Notice of Inquiry (Docket 21310) on quadriphonic FM radio broadcasting, in which all interested parties were asked to comment on whether the FCC should adopt standards for 4-channel broadcasting. The Commission said that the purpose of the inquiry was to determine whether there was sufficient public and industry interest to warrant the adoption of standards and, if so, to assist the FCC in formulating such standards. The comment period, originally scheduled to end on September 15, 1977, was extended to December 15, 1977; and, from all accounts, more than a thousand letters were received by the time the comment period ended.

Several other events occurred almost simultaneously, two of which tended to complicate the issue. First, coincident with issuing the 4-Channel FM Notice of Inquiry, the FCC also issued a second Notice of Inquiry (Docket 21313) regarding AM stereophonic broadcasting. A growing interest has been shown on the part of AM broadcast stations for this type of service, largely because of the competitive advantage gained by FM stations over the last decade. This advantage has been attributed by many to the fact that FM stations can transmit stereo program material while AM stations must transmit monophonic programs. Many industry experts feel that the FCC is more likely to pay attention to AM stereo broadcasting before it ever considers the problem of 4-channel FM transmission.

The second event that occurred was sponsored by the FCC itself. The Commission was concerned that the NQRC had only included one matrix system in its report, and had *not* involved subjective listening evaluations of either the QS matrix system (developed by Sansui Corporation of Japan) or the SQ matrix system (originated by CBS in the U.S.). As they pointed out, since the work of the NQRC was completed, much-improved logic and phase cancellation decoders were designed and developed for the QS- and SQ-systems. As a result, the FCC felt that available test data comparing localization and musical preference for 4-4-4 (discrete), 4-3-4 (semidiscrete, using three channels of transmission to broadcast four channels of information) and 4-2-4 (matrix-encoded using two channels for transmission) quadriphonic systems is not complete with respect to presently available technology.

The FCC Lab decided to conduct its own listening tests, including the best implementation (based upon the listener's choice) of the QS format, SQ format and the British-sponsored BBC Matrix H systems, as well as the discrete 4-channel tapes. The results of these tests were issued by the FCC in August, 1977. In addition to judging quadriphonic performance, listeners were asked to evaluate the compatibility of the different formats—that is, how well the music was reproduced stereophonically and even monophonically—an important criterion in any decision affecting quadriphonic broadcasting standards.

The results of these tests have been interpreted by different listeners in different ways. Since, on an overall basis, listeners agreed that the direct 4-channel

tape reproduction was the best, supporters of discrete 4-channel broadcasting are claiming a victory. Since, of all matrix systems tested, the CBS-developed SQ system (with its sophisticated logic decoder) was favored, CBS has also claimed a victory and has, in fact, suggested that the FCC not only *refrain* from enacting discrete 4-channel broadcast standards but actually set quadriphonic standards specifically endorsing the SQ format as the *only* matrix suitable for broadcast over FM channels.

Before we examine the logic (excuse the pun) of this argument, let's briefly review how the five proposed discrete 4-channel FM systems operate. All five systems are very similar. In fact, insofar as monophonic and stereophonic performance on existing FM tuners is concerned, the systems are identical. This similarity is a basic requirement of any quadriphonic system, since they must present uncompromised FM stereophonic and FM monophonic performance. Where the systems differ slightly is in their treatment of SCA (*S*ubsidiary *C*ommunications *A*uthorization) services, such as background music channels now broadcast as piggy-back subcarriers on FM stations on a private, point-to-point subscription basis, which, according to the FCC, should be provided for in any new standards to be proposed.

Monophonic compatibility

Assume that there are four inputs: Left-front (L_f), Right-front (R_f), Left-back (L_b) and Right-back (R_b). To preserve monophonic compatibility, the monophonic channel or baseband of the FM transmission (the region from 30 Hz to 15 kHz) must contain an equal summation of these four input signals designated as $M = L_f + R_f + L_b + R_b$. For stereo compatibility, the four signals are grouped as follows: $L_t = L_f + L_b$ and $R_t = R_f + R_b$. The values of L_t and R_t correspond to the left-total and right-total signals that should be heard in stereo. Just as in stereophonic broadcasting, they are also assigned to a difference subcarrier channel, as follows: $Y = (L_f + L_b) - (R_f + R_b)$. When these two signals are received by a standard stereophonic tuner or receiver, they are decoded as follows:

$$L_t = \frac{M + Y}{2} = L_f + L_b$$

$$R_t = \frac{M - Y}{2} = R_f + R_b.$$

Because of quadriphonic playback requirements, it is clear that two more transmission channels are needed, since, to solve for four unknowns, you must have four equations. The two additional transmission channels are defined as X and U, in which:

$X = (L_f + R_f) - (L_b + R_b)$ and

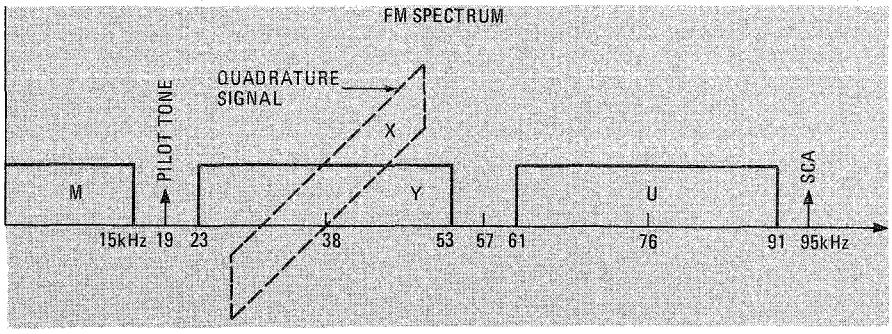

FIG. 2—FREQUENCY SPECTRUM shows how the two additional channels are added to an FM broadcast. This technique is used in the RCA and Quadracast discrete systems.

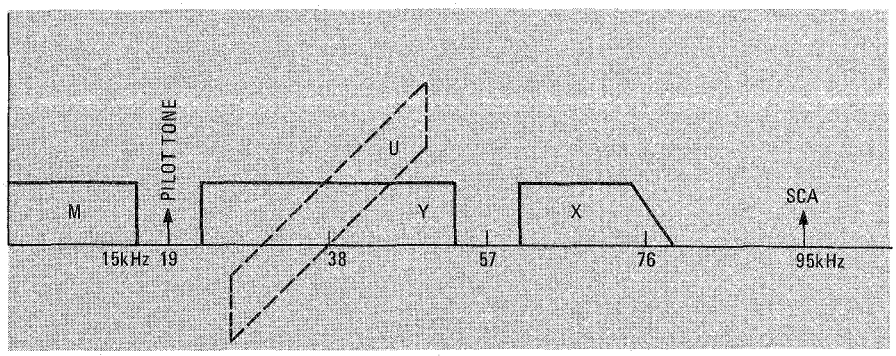

FIG. 3—FREQUENCY SPECTRUM of the GE broadcast system. The X transmission channel is added as a vestigial sideband.

$U = (L_f + R_b) - (R_f + L_b)$.

We will show how all four signals can be accommodated in a single FM transmission. But, first, let's examine what the 4-channel decoder must do after it has recovered signals M, Y, X and U to solve for the four original, discrete signals:

$$L_f = \frac{M + Y + X + U}{4}$$

$$R_f = \frac{M - Y + X - U}{4}$$

$$L_b = \frac{M + Y - X - U}{4}$$

$$R_b = \frac{M - Y - X + U}{4}$$

Figure 1 shows the principle of discrete 4-channel FM broadcasting. The question is where to assign the extra transmission channels X and U, and how to allow for continued SCA transmission. Figure 2 shows the scheme used by two of the five proponents, Quadracast System, Inc., and RCA. The newly required X channel is centered at a frequency of 38 kHz (similar to the older Y channel required for stereo), but it is in quadrature with the Y channel. This means that the X channel will not be detected by a stereophonic receiver but by a properly designed 4-channel receiver having a synchronous detector designed for that quadrature signal. The U channel is transmitted via a new subcarrier signal centered at 76 kHz (four times the 19-kHz pilot-carrier frequency). The QSI format further proposes that the SCA channel be moved from its present frequency of 67 kHz to 95 kHz and that it be band-limited in order not to interfere with adjacent broadcast channels.

RCA proposes an additional scheme that allows the SCA to remain where it presently is. This is the so-called 4-3-4 or semidiscrete system mentioned earlier in this article. This system uses only three transmission channels (the U channel is dropped from its 76-kHz position in the spectrum), leaving room for the SCA channel at a frequency of 67 kHz. In this system, the recovered four channels include the following original signal components:

$$L_f = L_f + \tfrac{1}{3} L_b + \tfrac{1}{3} R_f - \tfrac{1}{3} R_b$$
$$R_f = R_f + \tfrac{1}{3} L_f + \tfrac{1}{3} R_b - \tfrac{1}{3} L_b$$
$$L_b = L_b + \tfrac{1}{3} L_f + \tfrac{1}{3} R_b - \tfrac{1}{3} R_f$$
$$R_b = R_b + \tfrac{1}{3} L_b + \tfrac{1}{3} R_f - \tfrac{1}{3} L_f$$

The last three components in each equation are crosstalk terms, but overall separation from one channel to any other channel is still just a bit less than 10 dB. This RCA option would be strictly up to the station owner (who wants to have an SCA subcarrier signal at 67 kHz), and receivers designed for regular 4-4-4 operation would require no modifications for the 4-3-4 system.

Another system, using the same baseband signals as those shown in Fig. 2, is the Cooper-UMX system. This scheme differs from the foregoing explanation in that it uses phasor encoding of the four input signals to create three different playback modes: A 4-2-4 matrix (similar to the QS- or SQ-matrix encoding), a 4-

3-4 playback scheme similar to the RCA optional system, and, finally, a full 4-4-4 discrete mode.

Frequency assignments for the General Electric system are shown in Fig. 3. The fourth X channel is transmitted as a set of vestigial lower sideband signals at a frequency of 76 kHz. This allows an SCA channel at a 95-kHz frequency with a greater guard band between it and the adjacent X channel subcarrier as compared with the RCA option.

Finally, Fig. 4 shows the Zenith proposal. The fourth transmission channel, the X channel, is placed at a 95-kHz frequency and uses lower sideband signals only, allowing for SCA transmission to take place at its currently assigned 67-kHz frequency. The Zenith system also uses an encode/decode noise-reduction system, similar to the Dolby system, in order to maintain a lower overall noise level; this helps to counter in part the signal-to-noise degradation that occurs whenever the spectrum width of a transmission system is increased.

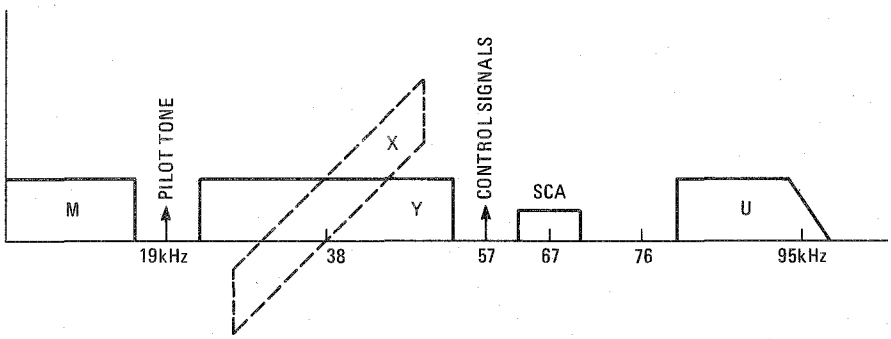

FIG. 4—ZENITH PROPOSAL places the SCA subcarrier at 67 kHz. This system also incorporates a noise reduction scheme.

Argument against a matrix standard

Proponents of the matrix system that was favored by the FCC's panel of listeners believe that this format should be approved as a standard at this time and that no discrete systems should be approved. What would this mean to the listening public? Admittedly, if a listener equipped his or her system with a sophisticated (and expensive) logic decoder such as that used in the FCC tests, results would approximate (but still not equal) those obtained with discrete 4-channel program material. However, if a simple matrix decoder were used, results would be far poorer than those obtainable from discrete program sources. In fact, some stations have been broadcasting matrix-encoded program material (in both QS- and SQ-formats) for some time and public reaction has been anything but enthusiastic. Locking into a matrix system as an FM standard at this time would halt further attempts to improve the matrix idea or to develop other (and perhaps better) matrix formats.

However, suppose the FCC selects one of the five discrete systems as a standard and suppose, further, that matrix programming improves substantially. In that event, there would be nothing to prevent a station from purchasing one (and only one) super-matrix-decoder—even a very expensive one—and *first* decoding the matrix-encoded source material into four discrete channels *before* it is transmitted. The home listener would *not* have reproduction quality determined by his or her financial limitations, since optimum decoding would take place at the station before transmission. This approach would keep the doors open for further improvements in matrix technology and would have many other advantages as well. FM stations could then transmit any and all formats of quadriphonic program material (instead of being limited to one specific matrix approach). Four-channel taped productions could be freely interchanged from one station to another, since no encoders or decoders would be required. Discrete broadcasts have proved to be fully compatible with all existing monophonic or stereophonic receivers. Furthermore, the matrix system still imposes certain artistic limitations upon record producers. A vocalist, for example, cannot be positioned at center-rear in the SQ system if full stereophonic and monophonic compatibility is to be maintained. Such limitations, although of relatively minor significance, are *not* imposed with any discrete system.

By the time you read this, the dates for filing comments and reply comments with the FCC will have passed. Nevertheless, we suspect that the FCC is not going to make any hasty decisions regarding 4-channel broadcasting. It does seem that by choosing a discrete broadcast standard, the FCC would let the final decision as to which kinds of quadriphonic records sound better remain where it belongs—with the public. A decision in favor of any matrix system as a standard would, we believe, be tantamount to taking away that freedom of choice from the music listeners of this country. **R-E**