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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Weather Service

Application of Multiplex Channels of FM Broadcast Stations to Public Weather Dissemination Needs

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APPLICATION OF MULTIPLEX CHANNELS OF FM BROADCAST STATIONS TO PUBLIC WEATHER DISSEMINATION NEEDS

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FIGURES

ABSTRACT

The full bandwidth of only relatively few of the FM broadcast channels is being effectively utilized. In effect this constitutes a wasteful underutilization of the radio frequency (RF) spectrum. This report discusses the possibility of exploiting the multiplexing potential inherent in commercial broadcasting systems to provide mass dissemination of weather information, forecasts, and warnings.

APPLICATION OF MULTIPLEX CHANNELS OF FM BROADCAST STATIONS TO PUBLIC WEATHER DISSEMINATION NEEDS

1.0 INTRODUCTION

The National Weather Service operates about 35 continuous weather broadcasting stations along the Gulf and Atlantic coasts and at scattered population centers throughout the United States. These are low-powered narrow-band transmitters operating in the 162MHz range. Programming is handled by local Weather Service Offices using cartridge-type tape handling equipment. This studio equipment is located in the Weather Service Offices and is connected to adjacent or remotely located transmitters by cables, telephone lines, or a VHF radio link.

After its initial limited use for dissemination of aviation weather information, the program grew in response to needs generated by marine interests. Over the past ten years programming has been broadened to cover a wide variety of special and general interest weather information. A few years ago the Weather Service undertook an energetic program of expanding the network with an ultimate goal of serving the general public throughout the country. It is estimated that this will require almost 200 stations, representing a substantial capital investment and, over the years, a very significant recurring cost.

Public response has been less than encouraging, due in part to public indifference bordering on apathy, and in part to the high cost of receivers capable of good reception of the relatively weak signal in the VHF band, or the cost and inconvenience of installing an adequate receiving antenna. It has been demonstrated that the present VHF-FM broadcasting system is very effective in serving those who are sufficiently motivated by their special interests in weather information to acquire adequate receiving equipment. There is little evidence to show that any significant progress has been made in motivating the public at large. The inherent advantages in the use of commercial facilities operating in the FM broadcast band offer some interesting possibilities for circumventing the most visible problems standing in the way of effective mass public weather dissemination; namely, public indifference and cost.

2.0 COMMERCIAL FM BROADCASTING

The commercial FM band occupies the 20MHz portion of the RF spectrum between 88 and 108MHz and is divided into 100 (actually 99) channels, each 200KHz in width. To provide adequate station separation a 50KHz guard band is established by limiting the maximum deviation of any channel to ±75KHz from its center frequency, hence 100% modulation will cause the carrier to swing 75KHz above and 75KHz below the "assigned" frequency, the lowest of which is 88.1 MHz and the highest, 107.9MHz. The deviation is a function of the amplitude of the modulating signal, not its frequency, which comes into play in a mathematically related way that will be mentioned next.

The maximum audio frequency transmitted is 15KHz which provides excellent fidelity. Stations broadcasting monaurally limit the amplitude of the modulating signal to produce only 90% modulation (±67.5KHz). This limitation is related to the aforementioned affect of the frequency of the modulating signal. Frequency modulation by its nature creates a broadband signal by taking power from the unmodulated carrier and forcing it into sidebands on each side of the center frequency. Significant sidebands (greater than 1% of the unmodulated carrier) must fall within the baseband, which for FM broadcasting is ±75KHz (identical to the maximum permissible deviation). Sidebands occur at multiples of the modulating frequency so for 15KHz they would exist at 15, 30, 45, 60, 75, 90KHz and so on. (See Figure 1.) Those at the higher multiples are of lesser magnitude than the fourth pair which in the case shown (100% modulation with a single 15KHz sinusoidal audio signal) is the largest. If the frequency of the audio signal is reduced to 5KHz and the modulation level is maintained at 100% (±75KHz deviation) the distribution of sidebands shown in Figure 2 will result. From these simplest possible modulation patterns it can be seen that the pattern arising from "normal" programming; such as, say, some of Montovani's music, would be enormously complex, and the theory and mathematics virtually impossible. The practical application deals with the integrated program material as a whole, taking advantage of the fact that maximum audio amplitudes seldom exist at the higher audio frequencies which tend to produce stronger sidebands beyond the baseband limit. (See Figure 1.) Thus, the modulation levels can be empirically set so the whole audio "package" is transmitted within the prescribed deviation and baseband limits as illustrated in Figure 8 which shows typical broadband RF signals as they appear on a spectrum analyzer cathode ray tube (CRT) display.

3.0 FM STEREOPHONIC BROADCASTING

Effective June 1, 1961, the Federal Communications Commission authorized broadcasting on a compatible FM stereo multiplexing system. In this system the whole program is the sum of separate left and right (L+R) signals. The two are produced separately, combined electronically and used to frequency modulate the main carrier (See Figure 3), but at a maximum of only 45% with either L or R present without the other. At the same time the two are also combined with the phase of "R" inverted to produce L-R. This composite signal is used to amplitude modulate a 38KHz subcarrier which is simultaneously used to frequency modulate the carrier at a maximum of 45%, again with either L or R present without the other. The combined modulation will thus not exceed 90% and, as a result of the reduction in the program modulation level, significant sidebands coexist within the permissible baseband (±75KHz) and the remaining

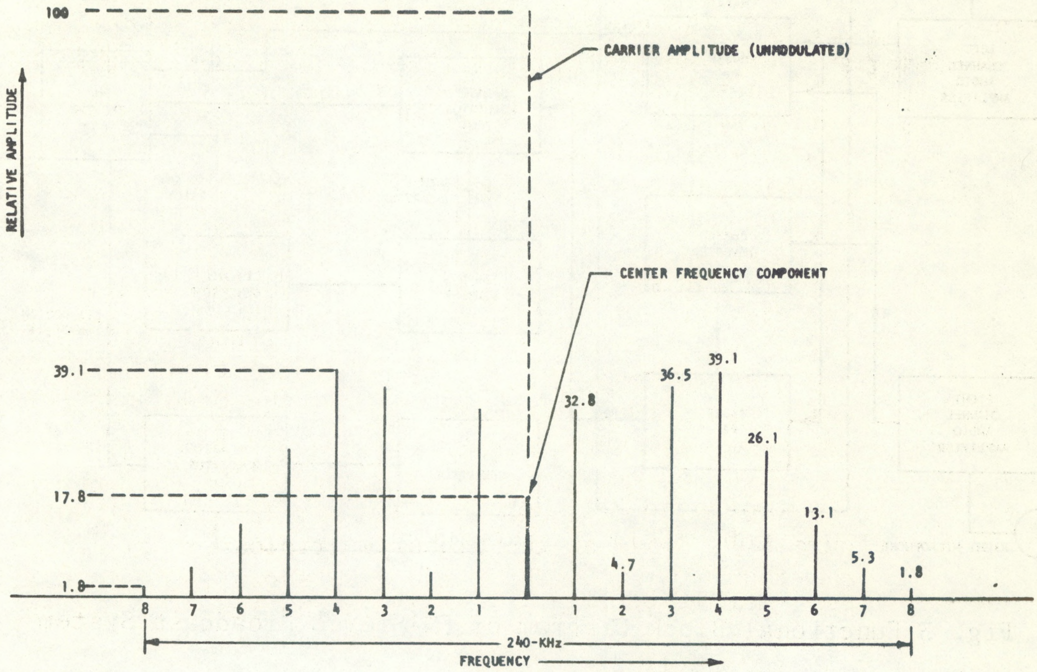


Fig. 1 Frequency Spectrum of FM Broadcast Signal

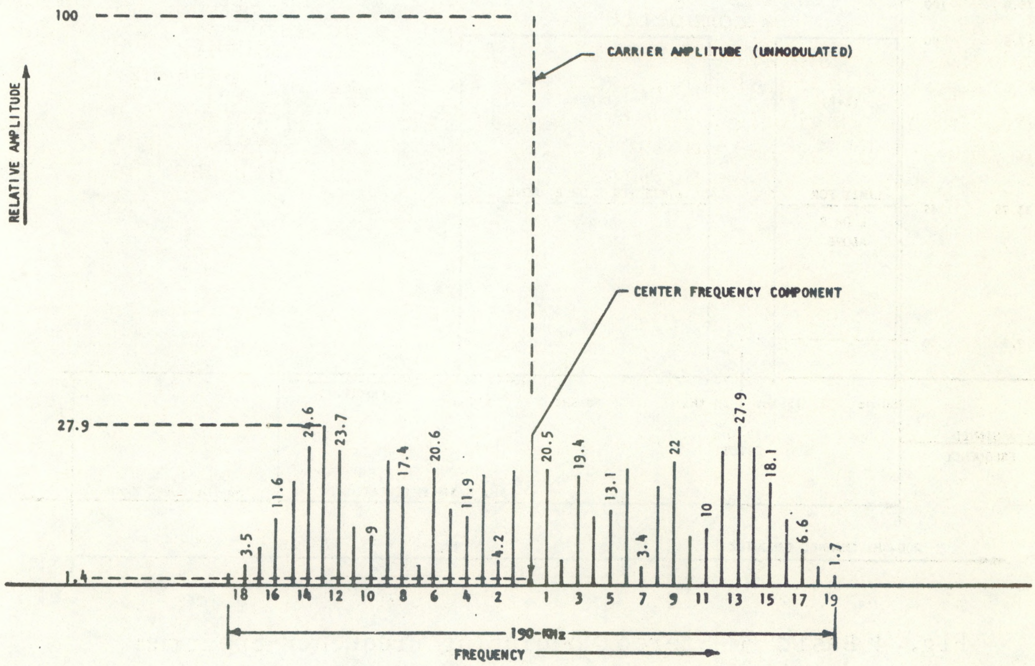


Fig. 2 Effect on FM Signal Spectrum of Lowering Modulating Frequency

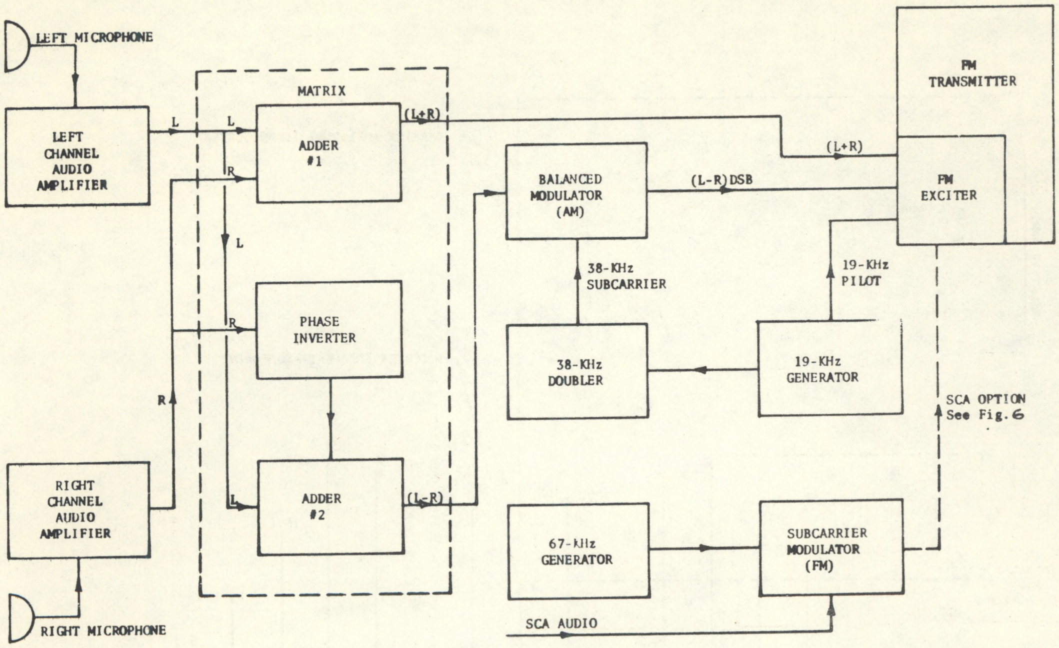


Fig. 3 Functional Block Diagram of FM-Stereo Broadcast System

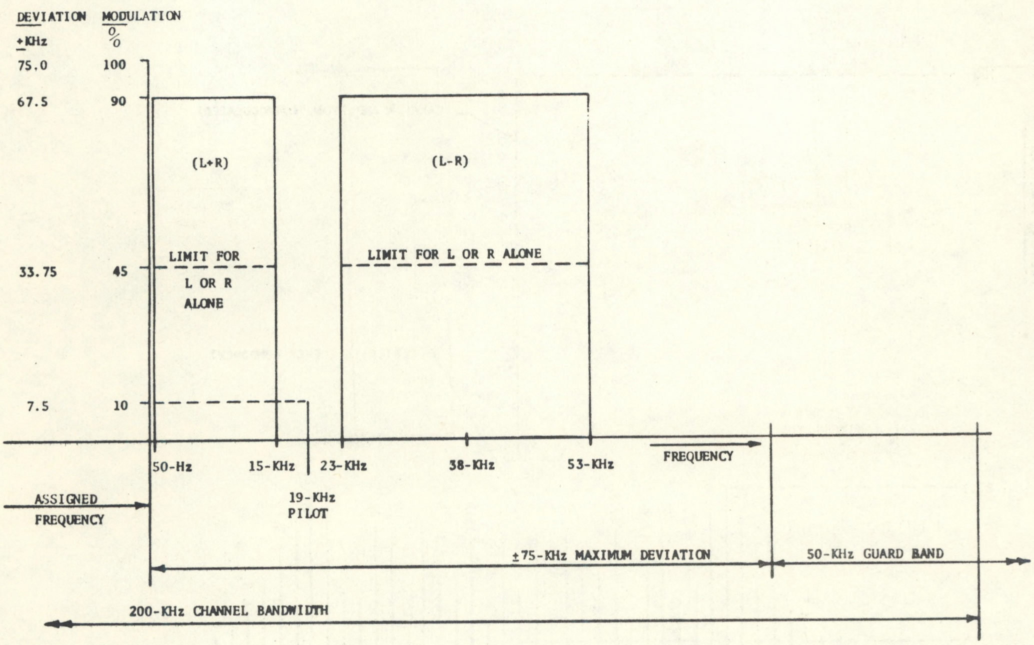


Fig. 4 Basic FM-Stereo Modulating Frequency Spectrum

10% of full modulation is available for the unmodulated 19KHz (pilot) subcarrier (See Figure 4.) This subcarrier must be present in the receiver to lock-in the phasing so the demultiplexing can be handled (as the reverse process of the multiplexing at the broadcast station), thus (See Figure 5):

(L+R) + (L-R) = 2L, hence L.

(L+R) + (-L+R) = 2R, hence R.

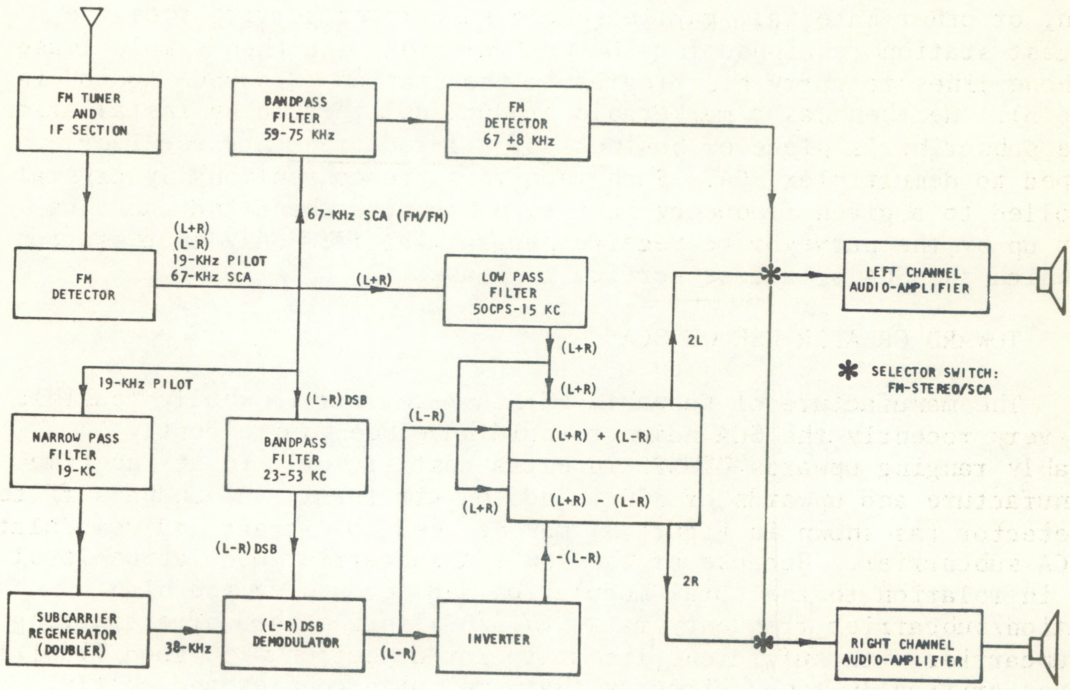


Fig. 5 Functional Block Program of FM-Stereo/SCA Receiver

4.0 SUBSIDIARY COMMUNICATIONS AUTHORIZATION (SCA)

The Federal Communications Commission has since authorized broadcasters to provide limited types of subsidiary services on a multiplex basis. This, too, can and is being done by a number of broadcasters to provide a variety of services but predominately background music (on a subscription basis) to commercial institutions simultaneously with normal programming (monophonic or stereophonic) within the ±75KHz permissible deviation and baseband. The L+R, L-R, and 19KHz subcarrier modulation levels are reduced so their combined maximum total is 90%, and the remaining 10% is used for a 67KHz frequency modulated SCA subcarrier (Figure 6). This reduction further suppresses the sidebands generated by the main program so fewer of those at the higher multiples rise to significant levels as can be seen by comparing the effect of 15KHz - 40% modulation (Figure 7) to that of 15KHz - 100% modulation (Figure 1). The SCA subcarrier is inserted at such a low modulation level (10% of the unmodulated main carrier) that the one significant sideband (nominally 67KHz) stays within the baseband. Typical broadband RF signals resulting from modulation with the combined array of these audible and super-audible frequencies are shown in Figure 8.

In practice the purveyor of an SCA service (if other than the FM station itself), be it background music, storecasting, detailed weather information, or other material, may lease the subcarrier service from the broadcast station (equipped for SCA multiplexing) and then simply lease telephone lines to carry his program to the station (See "SCA Audio" in Figure 3). He then has a marketable product deliverable by installation at the subscriber's place of business of a fixed frequency receiver equipped to demultiplex SCA. Such receivers are conventionally crystal controlled to a given frequency in the FM broadcast band and can thus be set up by the purveyor to receive programming from only that station from which the SCA broadcast service is leased.

5.0 TOWARD GREATER USE OF SCA

The manufacture of tuneable FM/SCA receivers is wholly feasible. Until very recently the SCA adjunct would have been quite costly (probably ranging upwards of $25 in extra cost if built in at the time of manufacture and upwards of $50 in add-on kit form). A bandpass filter and detector (as shown in Figure 5) may be used to extract and demodulate the SCA subcarrier. Because of the low SCA subcarrier modulation level (10%) in relation to the total modulation and because of the high deviation/subcarrier frequency ratio (7.5/67) this method of extracting the subcarrier with sufficient linearity for detection with good fidelity involves critically tuned circuits that are quite complex and costly.

Within the last year or so, the electronics industry began marketing various phase-locked-loop (PLL) configurations in integrated circuit (IC) form. The PLL is ideally suited to the task of locking onto and demodulating the 67KHz FM subcarrier. The interaction of the principle PLL functions shown in Figure 9 may be summarized thus: The Phase Detector generates an output voltage that is proportional to the difference, if any, between the phase of the incoming signal and the phase of the signal from the Voltage-Controlled Oscillator (VCO); the VCO free-running frequency has been set (by adjustment of an external resistance-capacitance network) to approximately 67KHz. This output voltage is amplified and applied to the VCO through the Low-Pass Filter and adjusts the VCO frequency to the incoming signal. Hence, the PLL will lock to the 67KHz subcarrier and, as its frequency shifts, the phase comparator output voltage will shift proportionally and continue

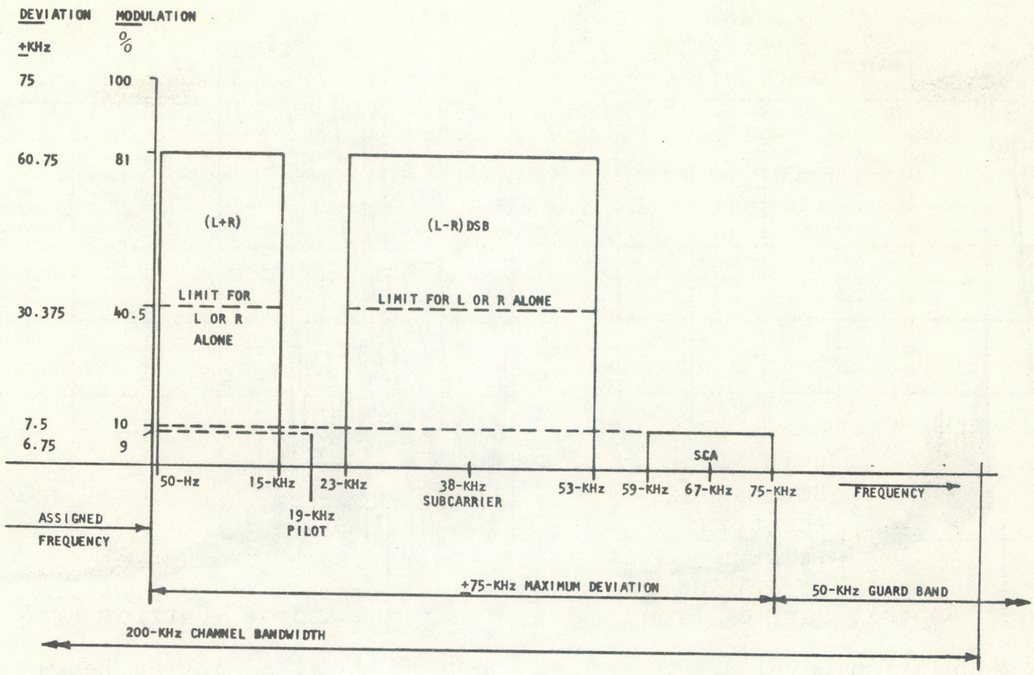


Fig. 6 FM-Stereo Modulating Frequency Spectrum with SCA Present

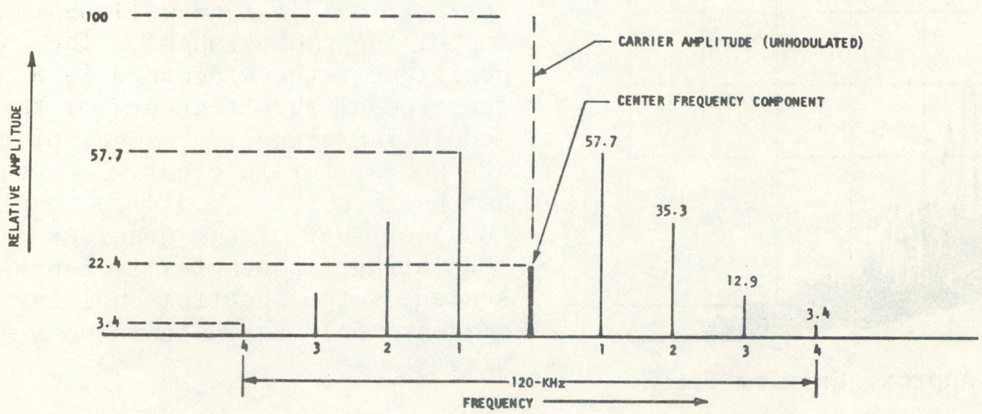
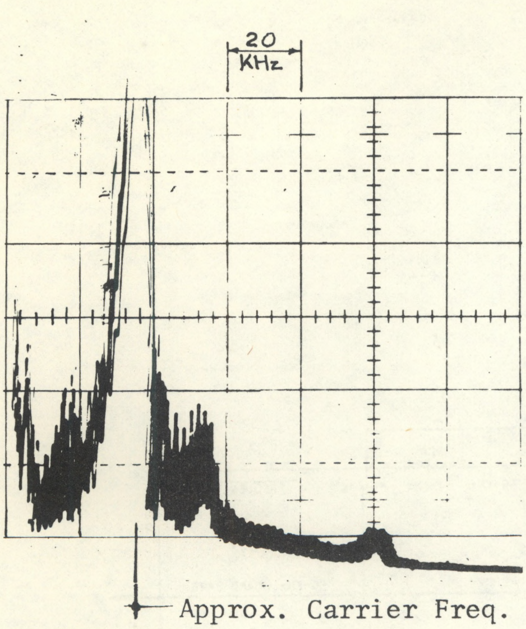
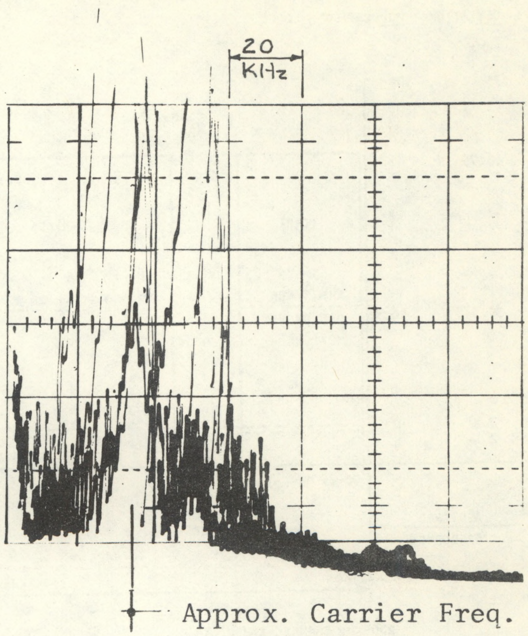


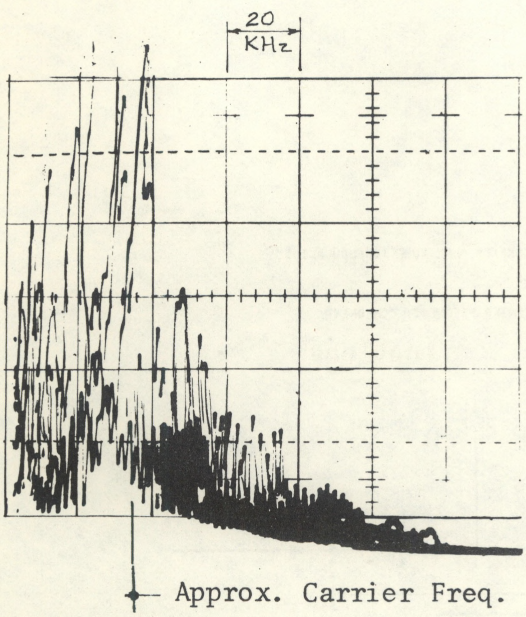
Fig. 7 Effect on FM Signal Spectrum of Lowering Modulation Level



8A Low Modulation Level



8B Moderate Modulation Level



8C High Modulation Level

As the modulation level increases more power is taken from the carrier and forced into the sidebands (the peak amplitude of the unmodulated carrier would extend well above the top of the photographs). The position of the sidebands is a function of the frequency of the modulating signal; presence of the SCA subcarrier is clearly evident. Neither its peak or average amplitude nor that of any other of the modulating frequencies is represented as the spectrum analyzer presents only an instantaneous view.

FIGURE 8. Typical Frequency Spectrums of FM-Stereo-SCA Broadcasting

BIBLIOGRAPHY

Behrend, William L., "Multiplexing Land-Mobile Base Station Signals on the Carrier of an FM Broadcast Station," IEEE Transactions on Broadcasting, Vol. BC-13, No. 2, New York, April 1967.

Department of the Army, "F-M Transmitters and Receivers," (TM11-668), Washington, D.C., 1952.

Federal Communications Commission, "Rules and Regulations," (TS III (68)-6), Washington, D.C.

Noll, Edward M., "FM-Stereo Receivers," International Correspondence Schools, Scranton, Pa.

Reference Data for Radio Engineers, Fifth Edition. Howard W. Sams Co., Inc., Indianapolis, Ind.

Signetics Corporation, "Data Sheet SE565/NE565."

Tary, John J., Livingston, Layne T., and Macken, Donald R., "Application of Multiplex Channels on FM and TV Broadcast Station to Educational Needs," ITS Technical Memorandum 128, Institute for Telecommunication Sciences, Boulder, Colo. March 1968, 28 pp.

Wood, Vincent, "Build an SCA Adapter for FM Reception," Unpublished manuscript.