



# The NOTEBOOK

BOONTON RADIO CORPORATION · BOONTON, NEW JERSEY

JAN 29 1962

## A MODULATOR FOR THE NEW FM STEREO SYSTEM

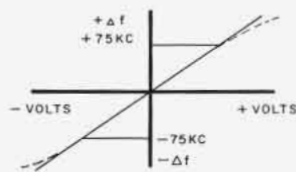
JOHN P. VAN DUYNE, *Engineering Manager*

For the past twenty-one years, the Boonton Radio Corporation has been recognized as a leader in the design and manufacture of frequency modulation signal generators. It is logical, therefore, that when FCC approved an FM Stereo Broadcasting System, as they did on April 20, 1961, that BRC should provide the market with a stable, easy to use, attractive, economical source of the multiplex signal for use with FM signal generators, or for direct use with receiving multiplex adapters. To this end, the 219-A has been designed.

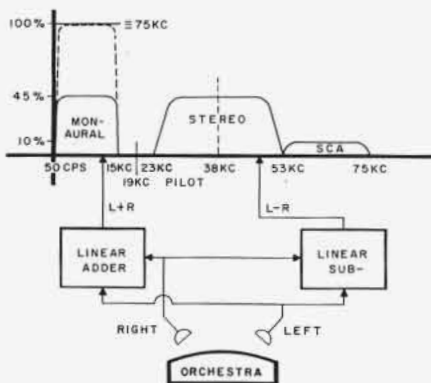
### THE FCC APPROVED SYSTEM

The system, approved by the FCC "Report and Order" dated April 20, 1961, and specified in FCC Docket 13506, provides for the simultaneous broadcasting of a main channel of monaural information, a separate sub-channel for the transmission of stereo information, and provision for one or more channels for Subsidiary Communication purposes. This latter assignment may be used for program relaying, "mood music", broadcasting for industrial or commercial purposes, etc.

The FCC approval of the stereo system came after an extensive study of the matter in general, and specifically, the work of the National Stereophonic Radio Committee which provided the medium for field testing and analyzing many of the various stereo broadcasting systems which had been proposed. The author will not attempt to discuss the work of this committee, which has been



"A"  
Modulation Characteristic



"B"  
Baseband Multiplex Spectrum  
Figure 1. New Stereo FM System

adequately documented, but will content himself with briefly describing the presently approved system.

Reference to Figure 1B will show the frequency spectrum of the baseband multiplex signal which is generated by the BRC 219A. The upper portion of this Figure (1A) shows a typical modulation characteristic of an FM signal generator. If the generator is reasonably linear, a single constant can be used to relate deviation of the radio frequency carrier to a voltage applied to the modulating terminals; i.e.,  $\Delta f = K E_{mod}$ . (1) With this in mind, the system may be more readily understood by confining one's attention to the baseband multiplex spectrum (Figure 1B), which is fed to the modulating jack of the FM signal generator.

One requirement confronting the designers of this system, that was of key importance to the FCC, was the problem of providing "compatible reception" with receivers already in the hands of the FM listening public. This has been achieved by a matrixing technique which is shown in the block diagram in Figure 1B. The assumption is made here that if there were two parallel-connected microphones "listening to" the output of a program source, such as an orchestra, that the listener to a monaural receiver tuned to this broadcast would hear a rather arbitrary summation of the audio outputs of these two microphones. It can be seen that in the new stereo system, these outputs are indeed summed and applied to the monaural channel; thus providing compatible reception.

In nonstereo broadcasting, the peak deviation resulting from the sum of the left and right outputs is allowed to reach 100% of system deviation, or 75 kc, for the previously approved monaural broadcasting system. In the case of the stereo system, this maximum deviation is reduced to the level of 90%, for reasons that will be discussed shortly.

Since the summed output of the left

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P. O. Box 390  
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Plant and Offices:  
Boonton Radio Corporation  
Green Pond Road  
Rockaway Township, New Jersey

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### YOU WILL FIND . . .

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and right microphones (L + R) are broadcast in this compatible manner, it simply remains to separately transmit information which is related to the instantaneous difference between the outputs of the Left and Right microphones. In order to minimize the bandwidth required for full fidelity (50 cps to 15,000 cps), this L - R information is transmitted by means of amplitude modulation of a subcarrier located at 38 kc. The subcarrier is suppressed to reduce crosstalk due to nonlinearity in the transmitter or receiver. Distortionless amplitude modulation of this suppressed carrier will, with signals not exceeding 15,000 cps in frequency, occupy the spectrum from 23 to 53 kc (38 ± 15 kc). This leaves a portion of the spectrum from 53 to 75 kc for a small amplitude Subsidiary Communications signal.

It is obvious to the reader that the system, described to this point, provides L + R in the normal audio frequency portion of the spectrum (50 to 15,000 cps) and the sidebands of the amplitude modulated suppressed carrier (L - R) information in the 23 to 53 kc region. However, since the 38 kc carrier is suppressed to less than 1% of system deviation, it would be extremely difficult to demodulate this information in a distortionless, low-noise manner. Therefore, a pilot carrier at exactly one-half the suppressed carrier frequency is transmitted at reduced deviation of the main carrier.

The 19 kc pilot carrier is specified to produce a deviation of the main carrier between 8 and 10% of the system deviation of 75 kc. Since this 19 kc carrier is located with a guard band of 4 kc on either side, as shown in Figure 1B, it is evident that a practical filter can be used to extract the frequency and phase information carried by this carrier. If the filtered pilot is doubled in frequency, maintaining the proper phase relationship, it may be used to demodulate the L - R information on the subcarrier by means of simple amplitude modulation

detectors in which the locally generated carrier is mixed with the L - R sidebands. The potential is also provided for the use of exalted carrier demodulation in the interests of good signal-to-noise ratio and low distortion.

Thus, we see that the multiplex stereo signal can be rather simply described by a plot of voltage generated versus the baseband frequency spectrum to 75 kc. The multiplex signal may also be described mathematically as follows:

$$E_{mx}(t) = \underbrace{(L+R) \sin(\omega_s t + \phi)}_{\text{monophonic baseband}} + \underbrace{\frac{L-R}{2} \left[ \cos\{(\omega_c - \omega_b)t - \phi\} - \cos\{(\omega_c + \omega_b)t + \phi\} \right]}_{\text{stereophonic sidebands of suppressed carrier } \omega_c} + \underbrace{a E_p \sin \omega_p t}_{\text{pilot carrier } 2\omega_p = \omega_c} \quad (2)$$

A major feature of the L + R, L - R matrix system is that time-sharing between the monaural and stereo channels is automatically provided. Thus, if at an instant in time, the outputs of the left and right microphones were synchro-

nous in frequency and identical in phase, a maximum output would exist in the L + R channel, and a zero output would exist in the L - R channel. Conversely, if the two microphone outputs were equal in amplitude and frequency, but opposite in phase, then the maximum output would exist in the L - R channel and zero in the L + R channel. If the maximum permissible deviation resulting from the L + R audio or from the sum of the L - R sidebands is

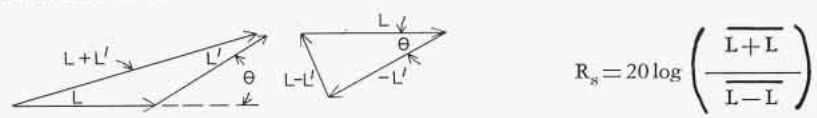
limited to 45% (33.75 kc) with either left only or right only by FCC, then it can be seen that no combination of Left and Right signals can add to produce more than 90% system deviation. Thus, the 6 db signal-to-noise degradation

ASSUME:

1. Left (L) signal only being transmitted
2. (L+R) channel response is such that its output differs from (L-R) channel as though it were multiplied by a transmission fact  $a \angle \theta = a(\cos \theta + j \sin \theta)$
3. Stereophonic separation  $\equiv R_s$   

$$R_s = 20 \log_{10} \left( \frac{\text{magnitude of output from Left channel}}{\text{magnitude of output from Right channel}} \right)$$
4. a. Let L  $\equiv$  output from L-R channel (Left signal only)  
 b. Let L'  $\equiv$  output from L+R channel (Left signal drive only)

VECTOR DIAGRAM:



$$L + L' = L + aL(\cos \theta + j \sin \theta) = L(1 + a \cos \theta) + j a L \sin \theta$$

$$L - L' = L - aL(\cos \theta + j \sin \theta) = L(1 - a \cos \theta) - j a L \sin \theta$$

$$R_s = 20 \log_{10} \sqrt{\frac{1 + 2a \cos \theta + a^2 \cos^2 \theta + a^2 \sin^2 \theta}{1 - 2a \cos \theta + a^2 \cos^2 \theta + a^2 \sin^2 \theta}} = 20 \log_{10} \sqrt{\frac{a^2 + 2a \cos \theta + 1}{a^2 - 2a \cos \theta + 1}}$$

CHECK:

1. If  $a = 1$ , and  $\theta = 0$ ;  $a^2 - 2a \cos \theta + 1 = 2 - 2 = 0$ ,  $\therefore R_s = \infty$
2. If  $a = 1$ , and  $\theta = \text{any value}$ ;  $R_s = 20 \log_{10} \sqrt{\frac{1 + \cos \theta}{1 - \cos \theta}}$
3. If  $\theta = 0$ , and  $a = \text{any real number}$ ;  $R_s = 20 \log_{10} \left( \frac{a+1}{a-1} \right)$

NOTE: These same equations may be used for the case where L-R channel output is multiplied by  $a(\cos \theta + j \sin \theta)$  but reference vector is now output of L+R channel.

Figure 2. Stereo System with Identical Inputs (Assumed as Left Only) Fed into the L+R and L-R Channels

which would result from transmitting Left and Right in the two channels is reduced to 1 db. The remaining 10% system deviation being reserved for the 19 kc pilot subcarrier.

There are several system transmission characteristics which must receive careful attention if the maximum capabilities of the system are to be reached. In any system that transmits stereo multiplex information, it is desirable that the maximum separation be retained between a signal which initiates output only in the Left channel or the Right channel. The ability of a system to produce the largest possible ratio of the signal in the left-hand loudspeaker at the receiving end, to the signal in the right-hand loudspeaker, when excited by a pure Left signal, is of interest (similarly for a pure Right signal). This ratio is termed "stereophonic separation".

It is a major endeavor of the newly approved system to maintain 30 db of stereo separation over the entire audio frequency range of 50 cps to 15,000 cps. If the system standards are adhered to, a broadcast transmitter can be assured of providing a signal capable of maintaining this separation. Considerable attention to detail is required to achieve this, however. Chief among these are the need for amplitude flatness of better than 3½% over the 50 to 15,000 cps frequency range. In addition, the time delay in the L - R channel must be so nearly equal to that in the L + R channel that not more than 3 degrees of differential phase shift exists between an audio frequency transmitted by one channel relative to the other channel.

This can be readily demonstrated if one will picture two parallel transmission systems driven with the same input and then take the outputs in these two systems and add them vectorily and then subtract them vectorily in two isolated circuits. Figure 2 illustrates the situation that exists in the stereo system when identical inputs (assumed as Left only) are fed into the L + R and L - R channels. If we consider that the transmission of the one channel differs from that of the other by a magnitude "a", and by an angle  $\theta$ , we can then solve for the residual output which will exist in the difference circuit. If this residual output is defined as  $R_s$ , we find that:

$$R_s = 20 \log_{10} \sqrt{\frac{a^2 + 2a \cos \theta + 1}{a^2 - 2a \cos \theta + 1}}$$

Figure 3 shows how stereo separation depends on values of "a" for any angle  $\theta$  from 0 to 30 degrees.

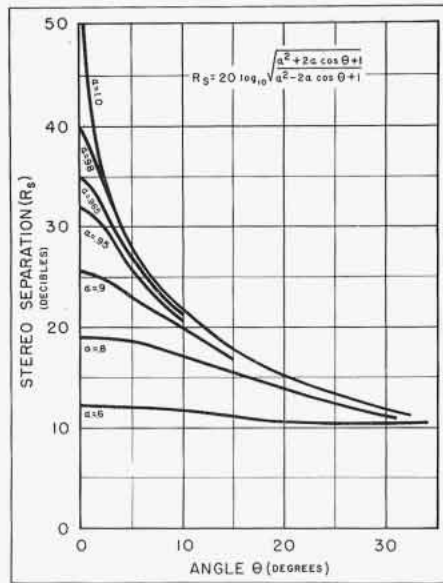


Figure 3. Stereo Separation ( $R_s$ ) Versus Angle  $\theta$

### TRANSMISSION OF THE MULTIPLEX STEREO SIGNAL

After the signal has been generated and exists in the form shown in Figure 1, or as described in equation 2, there are certain requirements placed on the components which transmit or process the multiplex signal if the stereo separation is to be maintained. These requirements are quite similar to those necessary to faithfully reproduce transient phenomena, in that the amplitude response must be quite flat and the time delay over the band must be of constant value. It is a well-known and unfortunate fact that most simple networks do not exhibit these characteristics over their entire passband.

A typical network that is of interest in connection with FM signal generators and receivers is shown in Figure 4. This figure illustrates a simple "constant k" low-pass filter section. The LC low pass is typical of the RF filters that exist between the modulation terminals and the reactive modulating element of most FM signal generators to prevent leakage of the carrier via the modulating leads. This filter is frequently one of the major limitations to the electric fidelity of the FM channel of such generators. It can be easily seen that only about 20% of the passband of the LC circuit meets the constant time delay criterion. Therefore, if constant time delay were a requirement to be maintained up to 50 kc, the circuit should actually have a bandwidth of 250 kc to provide negligible distortion of the multiplex signal.

It actually turns out that if the filter shown in Figure 4 were to contribute the maximum allowable delay error ( $3^\circ$  at 15 kc, or  $0.56 \mu\text{sec.}$ ) that it is possible to operate with the upper sideband of the FM multiplex system at  $0.29F_0$ , where  $F_0$  is the nominal cutoff frequency of the filter.

This fact is of considerable importance in selecting a suitable frequency modulation signal generator, since it shows that the actual modulation channel bandwidth will have to be 3 to 5 times 53 kc in order that phase-distortionless transmission can be relied upon. This is true of the BRC 202E Signal Generator, which is only 1 db down at 200 kc and exhibits essentially constant time delay up to 75 kc of the modulating frequency. There are many good FM signal generators of older design (for example, the BRC 202B) which have electric fidelity of the order of 15 to 20 kc. These are generally unusable with the stereo multiplex system, unless extensive work is done to predistort the signal for use with these narrower band generators. This can be done, but usually entails individual measurements and tests on a given generator.

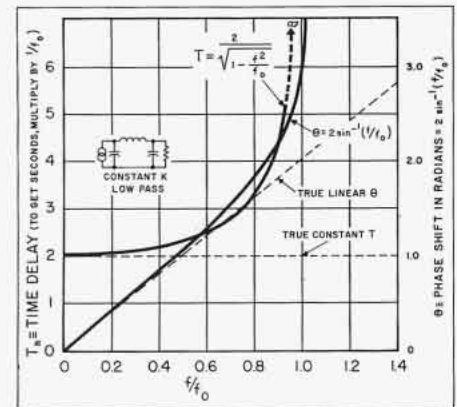


Figure 4. "Constant K" Low-Pass Filter Section

### DESIGN APPROACH TO BRC 219A

With this background, we are ready to turn to the factors guiding the design of the 219A. Reference to the block diagram of Figure 5 will quickly show that the "classical" approach to generating the signal has been used in this instrument. This was done to provide a maximum of stability, ease of understanding, and flexibility in providing the specified and certain desired "out of specification" signals for the purpose of receiver and multiplex adapter testing. The major objectives of the design were to achieve simplicity of use, operational

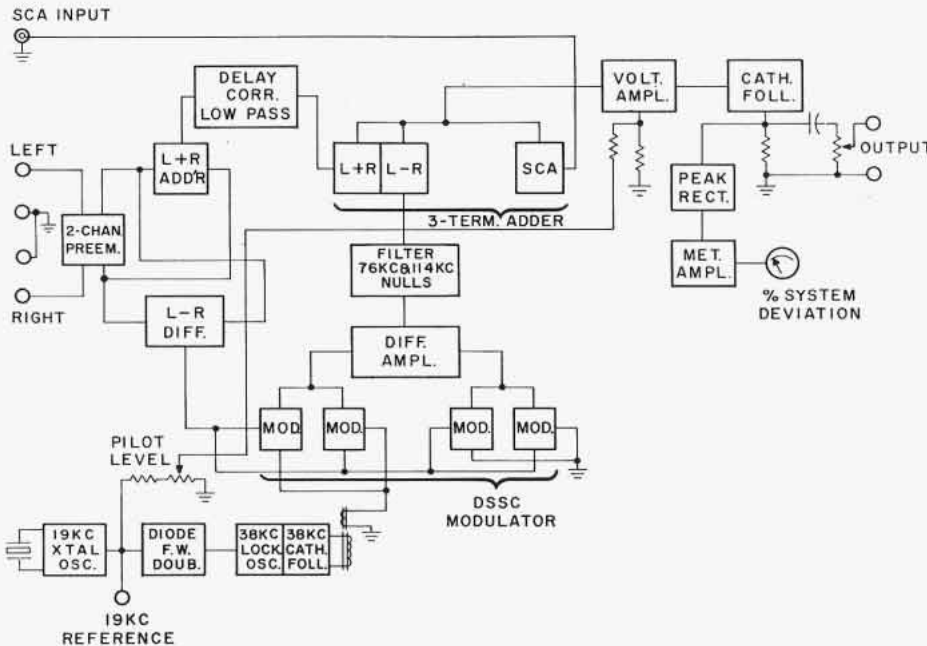


Figure 5. Block Diagram of the Type 219-A

stability, and self containment when used with the BRC 202E and comparable signal generators.

**INPUTS PROVIDED**

Separate left and right inputs of nearly identical phase and frequency response are provided. 1.7 volts rms typically are provided in left only or right only for 45% of system deviation. The input impedance is 10 k ohms. In addition, an input is provided for an FM subcarrier generator to simulate the SCA signals with which receivers may have to deal. This requires 1.0 rms volts into 10 k ohms, for 10% of system deviation.

It should be noted that the 219A is particularly easy to use with a BRC 202E, since audio frequencies from 50 cps to 10 kc, in several steps, may be supplied from the internal modulating oscillator of the 202E. In addition, a stable, balanced source of 1 kc is available inside the 219A. A normal-reverse switch is provided on the 219A panel to permit either of these two oscillators to be connected to the Left and Right channels. Thus, different frequencies are supplied for testing the two channels, and the variable frequency oscillator in the 202E can be used for fidelity measurements from 50 cps to 10 kc. Obviously, an external audio oscillator of any suitable type may also be used.

**CONTROLS**

The chart shown in Figure 6 lists the controls provided and the functions

which they perform. Particularly noteworthy are the matrix and mode switches. The matrix switch permits simple checking of the 219A for L - R null and L + R null, which permits a check on the internal alignment of the 219A. In addition, in these positions, outputs are provided using the internal 1 kc source, which permit crosstalk checking in a receiver or multiplex adapter between the L + R and L - R kc channels. This crosstalk is not to be confused with

stereo separation which is measured with a signal in only the Left or the Right channel. The mode switch permits an orderly checkout of the makeup of the multiplex signal, using the internal peak reading meter.

For other than the most advanced measurements, the meter integral to the 219A is all that is needed to verify proper setup of the multiplex signal. In addition, it can be used in conjunction with various positions of the mode switch and panel adjustments, to set up a non-standard signal of the type which may be needed to simulate propagation effects on the multiplex signal. For example, the pilot carrier may be adjusted over a range of 0 to 30% to simulate the effects of multipath transmission, or non-flat transmission systems.

Since many receivers will use phase-locked sub-carrier oscillators, variation in level of the pilot carrier is necessary to test their performance. Knobs are provided to adjust the pilot carrier level and the absolute output level of the 219A. A reference phase 19 kc output is provided to facilitate this.

The output level adjustment permits the use of the 219A with most FM signal generators. In use, it is only necessary to set the mode switch to the "SET" position, and to set the internal 1 kc level so the meter in the 219A reads 100% with the output connected to the FM signal generator. The controls of the FM signal generator are then set

FRONT PANEL CONTROLS	FUNCTION
NORMAL-REVERSE	Interchanges input channels, including internal 1 kc oscillator.
PREEMPHASIS	Inserts 75 $\mu$ sec. preemphasis in L and R channels.
1 KC	Connects and varies level of internal 1 kc oscillator to right channel.
MATRIX	Normal — See block diagram, Figure 6. L - R Null — Connects inputs of adder and subtracter to internal fixed 1 kc source. L + R Null — Connects adder and subtracter inputs to opposite polarity, equal amplitude internal 1 kc.
MODE	Set — Connects internal 1 kc source to output meter to set output for 75 kc deviation. L + R — Input signals go through adders to output; all else off; meter 100%. 19 KC — Pilot on only; meter calibrated 6-10%, set pilot level. 38 KC — Subcarrier on only, meter 0-10% to balance subcarrier. L - R — Pilot on; L + R off, meter 100%, inputs connected, set L - R gain. MULTIPLEX — All on; normal operation.
MULTIPLEX OUTPUT	Adjusts system output.
PILOT LEVEL	Adjusts level of pilot carrier.
SCREWDRIVER ADJUSTMENTS	FUNCTION
MODULATOR BALANCE	Fine balance adjustment for modulator.
L - R GAIN	Adjusts gain of L - R channel.
ZERO	Sets electrical zero of output peak voltmeter.

Figure 6. Type 219-A Control Functions

to provide 75 kc deviation. After that, if the output level control is not disturbed, the 219A will supply the proper relative levels of other signals which make up the multiplex spectrum.

Three screwdriver controls are provided: One permits adjustment of the suppressed carrier modulator amplitude balance, which although very stable, may experience changes from time to time as the tubes age differentially. Another, an L — R gain balance control, is provided for the same reason. The third control permits electrical zeroing of the output meter.

**SPECIFICATIONS**

Following are the detailed performance specifications of the 219A. When used with a BRC 202E, the combination accurately simulates an FM broadcasting station of superior performance to that specified in FCC Docket 13506.

modulator which transmits the L — R signal. The circuit used is shown in block diagram form in Figure 7. It uses four vacuum tubes biased to maximize the second order coefficient in the power series representing the plate current as a function of grid cathode voltage. In this circuit a balance of the 38 kc carrier is achieved which is more than 60 db below the fundamental components of plate current. In addition, excellent balance of the baseband audio signals from 50 cps to 15,000 cps is achieved. As the modulator generates the desired sidebands by means of the second order coefficient, it should be expected that fairly large second harmonics of both the baseband and the carrier would be generated. This is true for the basic modulator involving the pair of tubes shown in the left of the diagram. The subcarrier second harmonic at 76 kc is far enough removed from the desired output spectrum to be easily

baseband. This second harmonic is combined with the basic modulator output by means of the difference amplifier shown in the diagram, to produce a bucking baseband second harmonic output. The combined output baseband second harmonic is considerably more than 40 db below the desired sideband at 90% modulation.

As a result of this choice of modulator, an extremely stable circuit is provided which needs little output filtering. The baseband and carrier signals are supplied at low level and very low impedance, thus minimizing interaction and providing for extremely flat frequency and phase response, since no transformers need be involved in the broad band circuits. However, if the subcarrier signal source were rich in harmonics, unwanted outputs would result which could be only partially eliminated by a complex filter in the output of the modulator.

This problem has been greatly mini-

<p><b>Input Characteristics</b>                  LEFT (AND RIGHT) INPUT                  Frequency Range: 50 cps to 15 kc                  Level: 1.7 volts rms Left (or Right) only gives 45% output; simultaneous inputs yield 90% system deviation.                  Impedance: 10 k ohms                  Preemphasis 75 <math>\mu</math>sec.: May be switched in or out.</p> <p><b>SUBSIDIARY COMMUNICATIONS (SCA) INPUT</b>                  Frequency Range: 20-75 kc.                  Level: 1.0 volts rms for 10% system deviation, typically.                  Impedance: 10 k ohms</p> <p><b>Modulating Oscillator Characteristics</b>                  Frequency: 1 kc                  Accuracy: <math>\pm 10\%</math>                  Distortion: <math>&lt; 1\%</math>                  Connections: Switchable into Left or Right Inputs</p> <p><b>Output Characteristics</b>                  Level: 0 to 7.5 volts peak of Multiplex Signal.                  Load Impedance: Not less than 1500 ohms shunted with not more than 200 <math>\mu</math><math>\mu</math>f                  Residual Hum and Noise: 60 db or more below 100% output</p> <p><b>Metering:</b>                  Range: 0-10%, 0-100%                  Accuracy: <math>\pm 2\%</math> of full scale</p> <p><b>Matrix:</b>                  Normal: Output as selected by Output Mode Switch                  L + R Null: Left input equals — (Right) input for internal 1 kc oscillator only.</p>	<p><b>L — R Null:</b> Left input equals right input for internal 1 kc oscillator only.</p> <p><b>Output Modes:</b> Switchable to Set, L + R, 19 kc, 38 kc, L — R, and Multiplex</p> <p><b>PILOT CARRIER</b>                  Frequency: 19 kc                  Accuracy: <math>\pm .01\%</math>                  Level: 0-30% of System Deviation.</p> <p><b>MONAURAL (L + R)</b>                  Level: 0 to 100%                  *Fidelity: <math>\pm 1</math> db from 50 cps to 15 kc                  *Distortion: <math>&lt; 1\%</math>                  *measured at 45% System Deviation</p> <p><b>DOUBLE SIDEBAND SUPPRESSED CARRIER (L — R)</b>                  Carrier Suppression: <math>&lt; \frac{1}{2}\%</math> System Deviation                  Level: 0 to 100%                  *Distortion: <math>&lt; 1\%</math>                  *measured at 45% System Deviation</p> <p><b>SUBSIDIARY COMMUNICATIONS (SCA)</b>                  Level: 0 to 20% System Deviation                  Fidelity: 20 to 75 kc <math>\pm 0.5</math> db</p> <p><b>19 KC SYNCHRONIZING SIGNAL</b>                  Level: 0.5 volts rms Typical</p> <p><b>PHYSICAL CHARACTERISTICS</b>                  Mounting: Cabinet for bench use; readily adaptable for 19" rack mounting                  Dimensions: Height 5<math>\frac{1}{2}</math>", Width 16<math>\frac{1}{4}</math>", Depth 10<math>\frac{3}{8}</math>"</p> <p><b>POWER REQUIREMENTS</b>                  105-125 volts, 60 cps, 130 watts</p>
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**CIRCUIT DETAILS**

There are several novel circuits which permit the 219A to be stable and precise in its performance. A major factor in the design of such an instrument is the double sideband suppressed carrier

filtered out. However, the second harmonic of the baseband above 11.5 kc falls within the desired output spectrum of the modulator and therefore is not filterable. The second pair of tubes shown in Figure 7 corrects this problem by generating a second harmonic of the

mized by the use of a high purity 38 kc oscillator of the amplitude stabilized variety. This oscillator has high phase stability which is directly controlled by the second harmonic of a highly stable 19 kc crystal oscillator. A schematic of this circuit is shown in Figure 8. While

amplitude stabilized oscillators have been well known in the art, this is a simple, effective circuit of high stability which fits in nicely with the modulator previously described.

To avoid the use of expensive broadband phase linear transformers in the adders and subtractors, sum and difference amplifier circuits were used. The difference amplifier shown in Figure 9 maintains its discrimination against common mode signals by 60 db or more for a wide range of voltages and tube characteristics. It is used in two places in the 219A, as may be seen by reference to the block diagram (Figure 5). One use is for the initial subtraction of the Left and Right signals in the early portion of the block diagram. In addition, it is used in place of a broadband phase linear transformer to subtract the second harmonic contribution of the balance modulator from the main modulated signal source as described above.

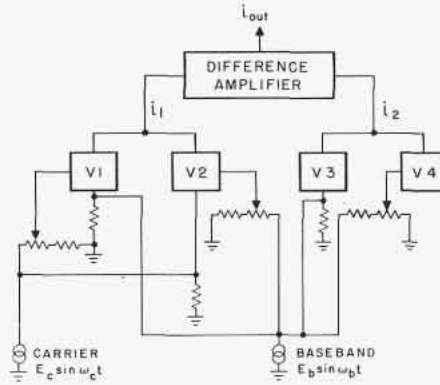
The use of the phase-locked oscillator provides a high degree of phase stability and at the same time has great freedom from unwanted phase modulation effects, thus providing a high degree of phase stability between the pilot carrier and the suppressed carrier.

**TESTS WHICH CAN BE PERFORMED WITH THE BRC 219A**

Reference to Figure 10 shows the 219A being used in conjunction with the BRC 202E FM Signal Generator for receiver testing. It has been pointed out that this combination represents an extremely versatile self-contained package for receiver testing. Obviously, the 219A may be used by itself for direct testing of a multiplex adapter as it supplies up to 7.5 volts peak of composite output into load impedances as low as 1500 ohms. It is obvious that the combination of these two instruments will enable many receiver test and alignment functions to be carried out expeditiously. While the following description will cover those tests which may be made on a completed FM stereo receiver, by deletion of the reference to the RF portion of the system, many of these tests may be performed directly on a multiplex adapter.

**Stereo Separation and Matrix Adjustment**

This is, of course, one of the major characteristics of a stereo system and will receive much attention from receiver designers and servicemen. It is a



$i_1$  contains the following terms:

$$C_2 E_c E_b [\cos(\omega_c - \omega_b)t - \cos(\omega_c + \omega_b)t] \text{ desired output}$$

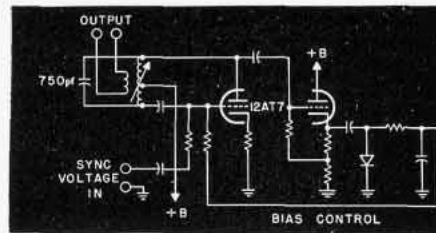
$$\frac{C_2 E_c^2}{2} \sin 2\omega_c t \text{ undesired carrier second harmonic}$$

$$\frac{C_2 E_b^2}{2} \sin 2\omega_b t \text{ undesired baseband second harmonic}$$

$i_2$  contains only  $\frac{C_2 E_b^2}{2} \sin 2\omega_b t$

$i_{out} = i_1 - i_2$ , thus cancelling undesired baseband second harmonic

**Figure 7. Block Diagram — Double Sideband Suppressed Carrier Modulator**



Typical 38 kc power output 0.05 mw  
 76 kc down > 45 db  
 114 kc down > 70 db  
 152 kc down > 75 db

**Figure 8. Low Distortion Amplitude Stabilized Oscillator**

simple matter to make these measurements at 1 kc since no external audio signal generators are required, nor are any external connections needed, other than the connection of the 219A to the FM generator or to the multiplex adapter.

In order to make this test, the matrix switch is placed in the normal position, the 1 kc oscillator is turned on, and the mode switch set to L+R. The amplitude of the 1 kc output is adjusted for 45% on the meter, and the mode switch is moved to the multiplex position. Under these conditions, a right only signal is being fed through the system. If the receiver has not been previously aligned, the matrix adjustments may be made for maximum 1 kc in the Right channel and minimum 1 kc in the Left channel. When the normal-reverse switch on the 219A is set to the reverse position, the reverse situation will be true, and the

stereo separation and receiver outputs may be measured at 1 kc.

If this information is desired at different frequencies, the internal 1 kc oscillator may be turned off and connection may be made between the AM terminals of the BRC 202E and the Left input terminals of the 219A using a special cable with a variable attenuator. Under these conditions, with the normal-reverse switch in the normal position, signal output will appear in the Left channel. The proper level may be set to correspond to 45% system deviation by again switching to the L+R position and adjusting the input signal level for 45%. Of course, this measurement may be made at other levels simply by adjusting the audio input level as required.

**Electrical Fidelity**

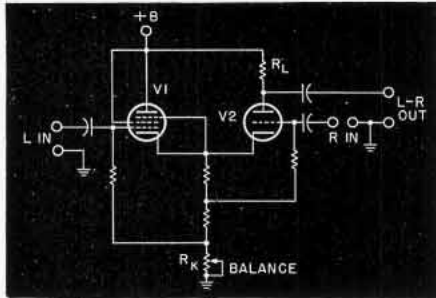
With the setup as described above, and by varying the frequency of the BRC 202E audio oscillator, it is possible to quickly determine the electrical fidelity between 50 and 10,000 cps of the receiver circuits. A simple output meter of adequate frequency response is the only additional equipment required. An external AF oscillator is required for measurement from 10 kc to 15 kc.

**L + R — L — R Crosstalk**

When the matrix switch is placed in the L—R null position, the Left and Right inputs are connected together to the internal 1 kc signal source. This should produce little or no signal to the input of the double sideband suppressed carrier modulator. Under these conditions, little output should come from the subcarrier detector in the multiplex device. Using this connection, and varying the RF signal level by adjusting the attenuator of the 202E, will show if overload effects from the receiver or the multiplex circuitry are occurring which would cause crosstalk prior to demodulation of the monaural and stereo signals.

**NON-STANDARD SIGNAL MAKEUP**

By manipulation of the pilot carrier level knob, non-standard levels of pilot carrier may be adjusted from 0 to about 30% of system deviation. The meter, in the 19 kc mode switch position, is calibrated from 6 to 10% only in the interest of maximum readability for the standard setting of the pilot carrier. Larger levels of pilot carrier may be metered by placing the mode switch in



Balance occurs when:

$$g_{m1} = \mu_2 \left( \frac{1}{r_{p1}} + R_k \right)$$

$$\text{or } R_k = \frac{g_{m1}}{\mu_2} \frac{1}{r_{p1}} = \frac{g_{m1} r_{p1} - \mu_2}{\mu_2 r_{p1}}$$

but  $g_{m1} r_{p1} = \mu_1$

$$\text{so } R_k = \frac{\mu_1 - \mu_2}{\mu_2 r_{p1}} \approx \frac{g_{m1}}{\mu_2}$$

if  $\mu_1 \gg \mu_2$

Figure 9. Inherently-Balanced Difference Amplifier

the L-R position with no audio input. As the 38 kc subcarrier is well nulled, the pilot carrier only causes the meter to read. The pilot may then be set for the desired percentage of system deviation as read on the 0-100% system deviation meter scale. When the mode switch

## BRC IN FULL SWING AT NEW PLANT

Boonton Radio Corporation is happy to announce that it is now situated in its new plant and offices, and that operation is again in full swing. The new facilities are located on a 70-acre site, near the recently completed Route 80 in Rockaway, New Jersey; approximately 7 miles from the old plant site. An announcement of the new plant address, telephone number, and mailing address is given on the first page of this issue. It should be noted that the Company is retaining the Boonton mailing address.

The administrative offices and engineering laboratory and the production sections of the building are interconnected at the upper level by a section which houses a cafeteria area and the model shop. This section acts as a buffer between the office and production areas.

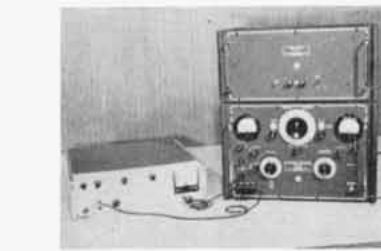


Figure 10. Type 219A and Type 202E Interconnected for Receiver Testing

is returned to the multiplex position, the desired excess pilot carrier will be present, and tests may be run.

Screwdriver adjustment for the L-R gain provides a range of  $\pm 10$  db of L-R relative to L+R gain.

### SUMMARY

From the preceding, it may be seen that the BRC 219A is a source of FM stereo multiplex baseband signals of considerable flexibility and involving some novel circuits in the interests of good performance and high stability. It should be re-emphasized that the combination of the 219A and the BRC 202E give the customer modulated RF stereo multiplex signals of a quality better than the FCC specification and in packages that are designed for stability of calibration, ease of control, and long life. The writer is indebted to W. N. Frick and R. W. Houskamp who contributed greatly to the design of this instrument.



The building is of ultra-modern design with exterior walls of pre-cast concrete and glass. The exterior walls of the office area are constructed almost entirely of tinted glass. These walls are recessed below the walls of the upper level, the overhanging upper level forming protection for a promenade which extends around the entire lower level. The recessed walls and the tinted glass provide protection against direct sunlight.

Our new plant is completely air conditioned and is equipped with the latest in production and laboratory equipment. Among some of the new facilities are a completely equipped plating room, a paint shop, and a cafeteria area. All of the other facilities have been enlarged and modernized.

The plant is designed on a modular basis to allow for future expansion. The unit now completed provides 60,000 square feet, or more than twice the area available in the old plant. Ultimate expansion calls for four modular units which will provide 320,000 square feet of working and storage area.

A series of articles about our new plant will be published in future issues of the Notebook.

### SERVICE NOTE

#### Adjustment of Q Dial Lock Tension on the Type 280-A

It is possible that, after prolonged use, the HIGH CIRCUIT Q and CIRCUIT Q dial locking mechanisms on the Type 280-A UHF Q Meter will require adjustment. To adjust the dial lock mechanisms proceed as follows.

- Using a No. 8 Allen wrench, remove the two setscrews that fasten the Q dial control knob to the control shaft.

NOTE: The procedure is the same for both the HIGH CIRCUIT Q and CIRCUIT Q dial lock mechanisms.

- Lock the Q dial with the Q lock control.

- Using a No. 4 Allen wrench, loosen the setscrew on the Q dial locking collar.

- Turn the locking collar clockwise to remove all tension on the collar.

- Turn the collar clockwise until it is just finger tight, then continue rotation for an additional 135° or about 3/8 of a complete revolution.

- Tighten the setscrew on the locking collar.

- Replace the Q dial control knob and tighten the two setscrews.

- Check the operation of the Q dial with the dial locked and unlocked. Operation should be smooth and positive. There should be no slippage with rapid movements of the Q dial in either direction.

### LAHANA & CO. APPOINTED BRC SALES REPRESENTATIVE

Boonton Radio Corporation is pleased to announce the appointment of Lahana & Company as exclusive sales representatives for BRC in Colorado, eastern Montana, Utah, and Wyoming.

## EDITOR'S NOTE

BRC Expands  
Sales Engineering Staff

We are pleased to report that BRC has recently expanded its sales engineering staff. This is in step with BRC's overall expansion program, which in recent weeks has seen the completion of a new plant providing vastly improved engineering and production facilities. This increase in the sales engineering staff was made to improve service, not only to direct sales customers, but to all of our customers, through our sales engineering representatives around the world.

Most of our readers already know the BRC sales engineers: Charles W. "Chuck" Quinn was introduced in Notebook 22; Willard J. "Will" Cerney's biography appeared in Notebook 25; and a story on Hans H. Schlott was published in Notebook 29. In addition to handling sales in our local area, Chuck, Will, and Hans are responsible for aiding in the development of new



applications; handling the introduction and initial evaluation of new products; participating in sales exhibitions, seminars, and meetings; and contributing to the BRC Notebook, BRC Bulletin, and other publications.

To better organize our sales service, we have split our local area into three territories: Chuck handles New Jersey and Eastern Pennsylvania; Hans covers the Metropolitan New York area; and Will has been assigned to the Metropolitan Philadelphia, Baltimore, and Washington, D.C. areas. While our sales engineers still make their headquarters at the plant, they regularly tour their

respective territories and, in case of an emergency, can generally be at a customer's door within hours. Old friends or new are encouraged to drop them a line or give them a call for application engineering assistance.

Since most of our readers will be in touch with the BRC sales staff, at one time or another, we would like to take this opportunity to introduce the entire group. In the photograph, from left to right, are: front row; Marion A. Derico, Domestic Order Processing; Evelyn D. LaHart, Export Order Processing; second row, Eleanor D. Matschke, Literature Requests; Grace L. Stone, Secretary to Sales Manager; Willard J. Cerney, Sales Engineer; back row, Frank P. Montesion, Technical Editor; Charles W. Quinn, Sales Engineer; Harry J. Lang, Sales Manager; Hans H. Schlott, Regional Sales Manager; Harry A. Schmidt, Technical Writer; and Bruce A. Barnes, Sales Coordinator.

All of these people are anxious to serve you. They may be reached by telephone at OAKwood 7-6400, or by TWX at Rockaway NJ 866.

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