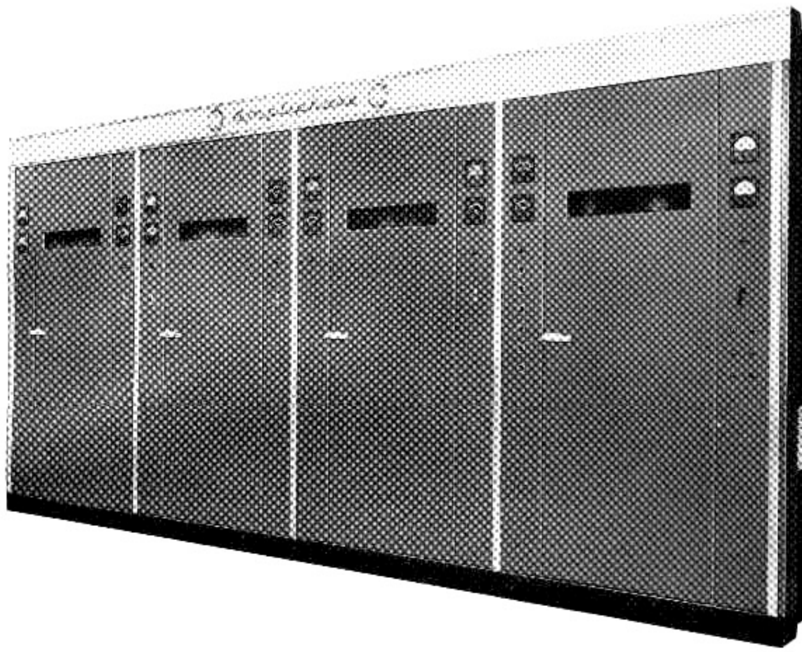


This is the 50,000 watt "Ampliphase" Transmitter now in operation at 12 major stations.

PRINCIPLES OF OPERATION OF THE *Ampliphase* TRANSMITTER

A Combination of Phase Modulation and Regulation of RF Drive to Produce 50 KW Output

by A. M. MILLER *and* J. NOVIK, *Broadcast and Television Equipment Division*

The *Ampliphase* system of modulation has been commonly described as a "Phase to Amplitude" process. It is that plus application of some additional circuit techniques. Otherwise, performance in accordance with the rigid specifications could not be achieved. Hence, performance records of the *Ampliphase* 50-kw Transmitter at 12 major stations point to three very specific benefits: economy of operation, increase in program coverage, and improved sound.

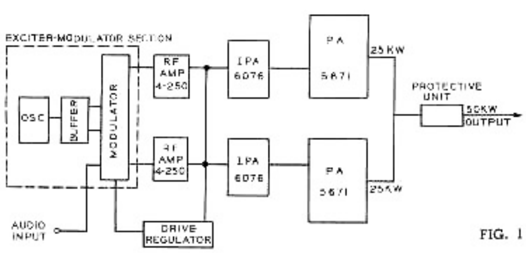


FIG. 1

Basic Operation

The general block diagram of the transmitter (see Fig. 1) shows the layout and various designations of the blocks; this should be studied carefully. If the modulator and drive regulator blocks are omitted, the remaining stages are shown in Fig. 2.

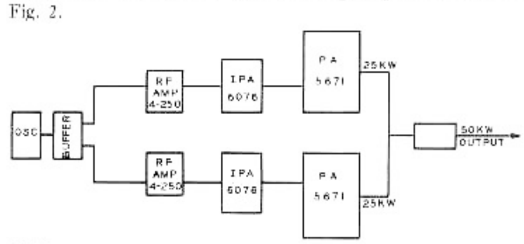


FIG. 2

An oscillator and buffer stage is followed by three broadband amplifier stages, with three identical ones running in parallel.

forming a second rf amplifier chain or channel. Then note that the channel outputs are connected to make the equivalent of two 25-kw transmitters operated in parallel to produce 50-kw of output power.

Exciter Modulator Section

Returning to Fig. 1, the complete block diagram, take from it the simplified exciter-modulator section, and unfold it in the form of another block diagram (see Fig. 3) and add to it, for the moment, a small combining network at its output, and consider it operable as a unit.

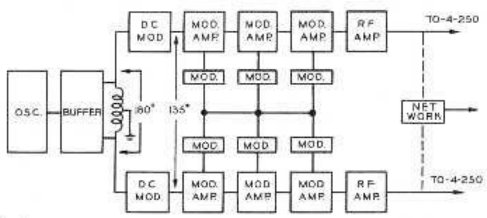
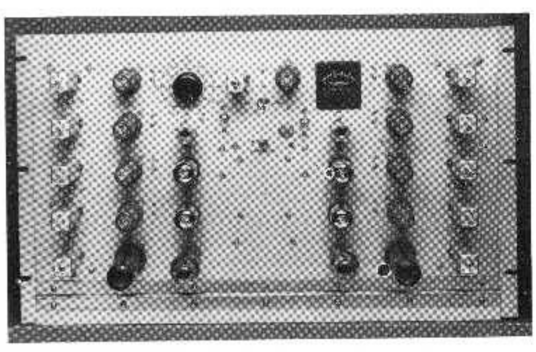


FIG. 3

Here a single crystal oscillator followed by a buffer amplifier stage, with the rf output divided by center-tapping the tank circuit to ground is shown. Then by connecting both ends of the coil to independent, identical rf channels, it becomes obvious that these two signals would be 180 degrees out of phase; furthermore, if the signals are recombined, zero output would result. Thus, there is a need for another stage in the respective signal paths, to provide appropriate phase shift that will prevent cancellation of the signals, and to provide an output of some desired value. This is accomplished by the stages designated as "dc modulators." They have been given a phase shift to 135 degrees. Following the "dc modulators" in each channel are three stages marked "Modulated Amplifiers," and a fourth, marked "rf Amplifier." The three modulated amplifiers in each channel are identical in circuit and function.



This is the exciter modulator unit, each channels separate components are mounted on the same chassis. In the Ampliphase transmitter two of these exciter-modulator units are provided, and duplication of these low power stages increases transmitter reliability.

Phase Relationships

The simplest approach to understanding the system is through vector analysis. Figure 4 shows vector "OC" representing current, and "OA" and "OB" representing the phase relationship of channels "A" and "B", thus the output is zero.

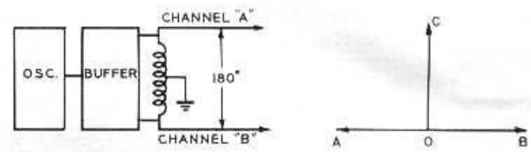


FIG. 4

However, if the phase difference between the two channels is shifted to 135 degrees (see Fig. 5), a certain amount of output current will result, as indicated by vector "OC_1".

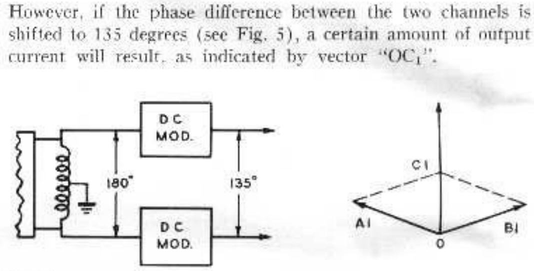


FIG. 5

Continued shifting of the phase on to a 90 degree difference, as shown in Fig. 6, causes the output current to double, as represented by vector "OC_2".

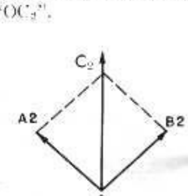
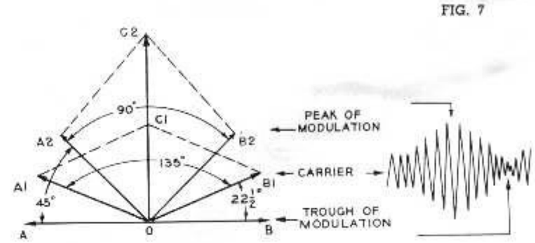


FIG. 6

A combination of the three vector drawings (Figs. 4, 5, and 6) provides a composite vector (see Fig. 7).

FIG. 7



Here a 180-degree phase difference produces zero output, and this corresponds to the trough of modulation. A shift to 135 degrees would provide a given current that can represent the carrier. Then, on to 90 degrees, note the load current is double with respect to 135 degrees. Doubling the current or increasing the power by four times produces a condition corresponding to the peak of modulation. If a phase difference of 135 degrees is designated as carrier, and an excursion in each carrier of ±22.5 degrees is utilized, then conditions of no output can be produced (corresponding to trough of modulation), and through a point where the load current will double (corresponding to 100 percent modulation).

Phase Shifting Circuitry

The block diagram of the exciter (see Fig. 3) shows that the phase shifting requirements can be readily accomplished. The methods used can best be explained by an examination of the circuitry in each contributing stage.

Figure 8 shows a simplified circuit diagram of dc modulator stage.

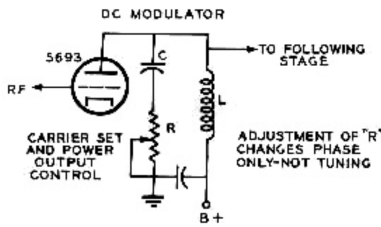


FIG. 8

It is simply an rf amplifier with a variable resistor in a low "Q" plate tank circuit, and the phase can be controlled by adjustment of this resistor. The values of "L" and "C" are selected so that a change in "R" does not change impedance, only phase.

Figure 9 shows how the two dc modulators are utilized together, with variable resistors on a common shaft to control the carrier.

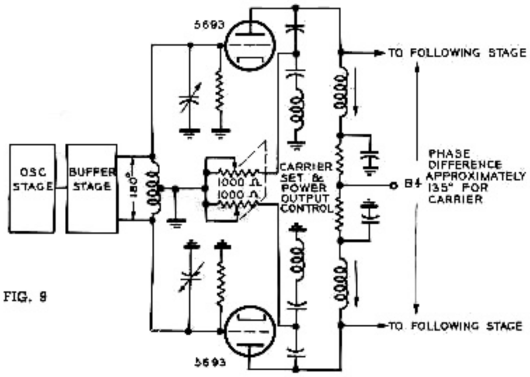


FIG. 9

Modulated Stages

Following the dc modulators, there are three identical stages in each channel, designated as "Modulated Amplifiers." Each stage is almost identical to the dc modulator, except that instead of a variable resistor in each plate tank circuit, a triode tube is substituted which serves as a variable resistor capable of variations at audio frequencies (see Fig. 10). As an audio signal is applied to the grid of the modulator tube, a phase modulated signal is produced in the tank circuit.

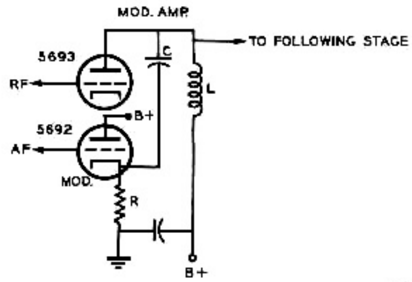


FIG. 10

Figure 11 shows how the two modulated amplifiers are connected in their respective channels.

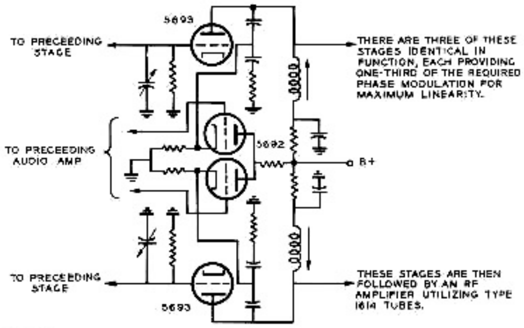


FIG. 11

There are three modulated amplifiers in each channel, making a cascade modulator. This circuit technique makes it possible to produce a phase modulated signal by the simple plate resistance method with negligible distortion. As mentioned earlier, a phase change of ±22.5 degrees is desired. A phase excursion of this magnitude in a single stage would result in distortion beyond specifications. By doing it in the cascade, the phase excursion is less than ±8 degrees per stage and after three stages produce a resultant ±22.5 degrees, with low distortion. Following the modulated amplifiers a conventional amplifier stage is used to provide isolation and drive to the first intermediate power amplifier. In the BTA-50G the output of each channel from the exciter modulator is fed to a series of three conventional broadband amplifiers, providing the necessary power gain to produce the desired 25-kw in each channel. These are combined for the 50-kw output.

Drive Regulation

To achieve a high degree of efficiency during modulation, and a high peak modulation capability with minimum carrier shift and distortion, a "Drive Regulator" is added. This technique contributes to a "Phase to Amplitude" system of modulation the element that completes the *Ampliphase* concept.

It produces a practical modulation process for high power AM transmitters that is both reliable and economical. The "Drive Regulator's" location with respect to the system is shown in Fig. 1. The simplified diagram of Fig. 12 shows how the output of the "Drive Regulator" is applied to the grids of the IPA stages.

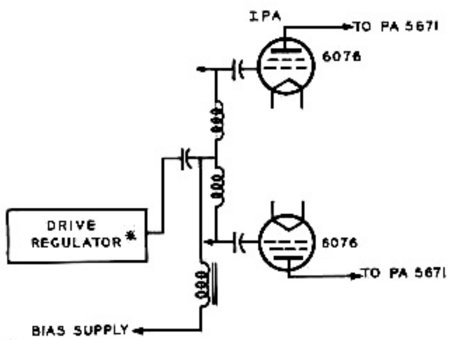


FIG. 12

The drive regulator is an audio amplifier with a cathode follower type output, utilized as a "dynamic bias control," functioning synchronously with the modulation process. It provides a variation of drive to the final PA stages, controlling the output currents in direct relationship to the load requirements at the various percentages of modulation. Consequently, the efficiency at average modulation is essentially the same as at carrier.

Consider for a moment, operation without drive regulation. At the peak of modulation (100 percent), each output tube must supply two times its carrier load current, while at the trough of modulation (100 percent), no load current is required. Therefore, the output tubes see an apparent impedance varying over a wide range during the modulation cycle. Under these conditions the rf plate voltage on the output tube would obviously not be constant. In result, the modulation peaks would not raise to the required value, and conversely, at the trough of modulation, the tubes would be over-driven as related to the output current requirement.

Vector Relationships

Again, a family of vectors can be used to illustrate and compare the current and phase relationships, depicting what happens to the vectors when drive regulation is applied. Not only is the phase location of the respective vectors controlled but their length (magnitude) as well.

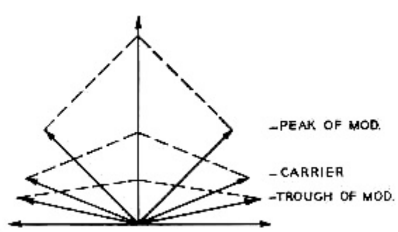
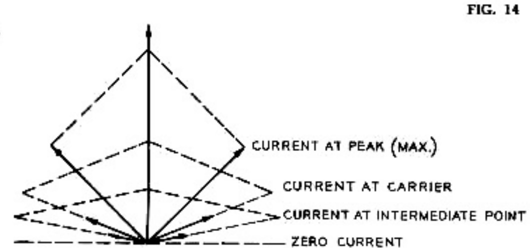


FIG. 13

In a constant current vector presentation as shown in Fig. 13, again it is obvious that from the trough of modulation (100 percent) to the peak of modulation, or the power change from zero to four times carrier, the rf plate voltage would swing from a very low to a very high value. However, if the current is varied along with phase, not only is a proper relationship of current and voltage to load achieved, but an improvement in efficiency is acquired as the drive is controlled to supply current only as needed. The vector presentation (see Fig. 14) depicts the variable current as well as the phase relationship.

FIG. 14



Linearity Control

Figure 15 shows a simplified diagram of the drive regulator stage. Note that it utilizes two intermediate stages in parallel, one with adjustable bias and adjustable input to allow increased output on audio peaks; and it is called a linearity stage. By the

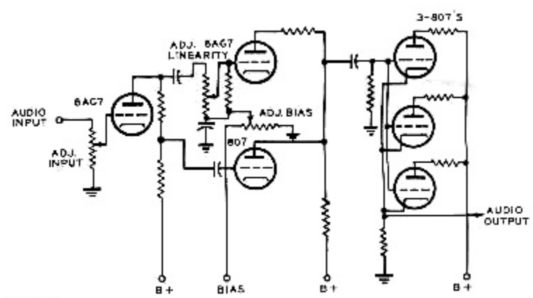


FIG. 15

adjustment on this stage, compensation for normal tube characteristic non-linearity can be achieved (see Fig. 16A). A slight increase on peaks makes up for this discrepancy, and provides a resultant as though the tube curve was straight, as indicated by the dotted line (Fig. 16B).

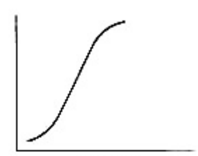


FIG. 16A


FIG 16B

Feedback

A small amount of overall feedback is used in the system. This is accomplished by sampling the rf output at the reflectometer in the transmission line. The reflectometer employs a balanced germanium diode detector, and is compensated to prevent regeneration across the audio spectrum. One further precaution is taken in that an adjustable diode limiter circuit is built into the phase modulator so that if high peaks or transients should occur, the phase shift will never exceed optimum or cross over on the peaks of modulation to change the feedback polarity.