RCA Broadcast Systems

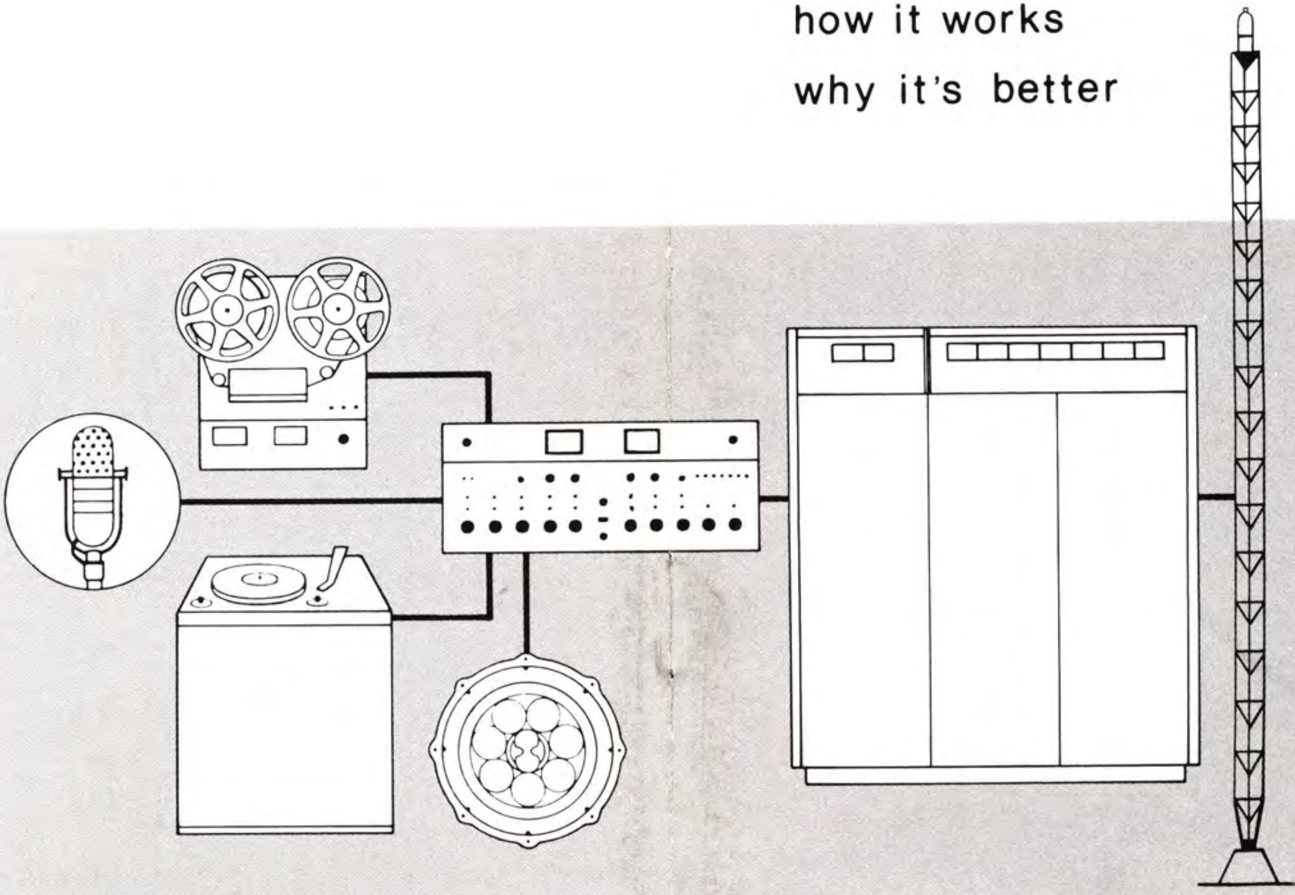
RCA

Ampliphase

what it is

how it works

why it's better



Radio Station Equipment Management
RCA Broadcast Systems
Camden, N.J. 08102

The purpose of this booklet is to help you understand RCA's Ampliphase — what it is, how it works, and why it sounds so much better than ordinary radio broadcast transmitters.

We introduced the first Ampliphase broadcast transmitter in 1957. The Ampliphase system has been in use ever since, first in our 250-, 100- and 50-kW transmitters, and later, in 10- and 5-kW models. Then, recently, we announced a far reaching simplification —, a completely solid state Ampliphase exciter — heart of all RCA Ampliphase transmitters and a new key to broadcast economy.

How we combined the many important benefits of Ampliphase in an AM transmitter that is easier to operate, lasts longer, and costs far less to run, is the subject of discussion in the next few pages. For your convenience, our material is presented in two sections:

SECTION I
AN INTRODUCTION TO AMPLIPHASE

WHAT IS AMPLIPHASE?

Ampliphase is unlike any other method of amplitude modulation. Yet it is quite simple and extremely efficient. It gives us the true high fidelity sound of FM, while retaining the super modulation capabilities of our AM transmitters. Ampliphase uses no audio transformers of any kind. Exciter *and modulator* are entirely solid state. RF output stages are efficient class C amplifiers.

Stripped of all embellishments, the Ampliphase system is simply the adding and subtracting of the outputs of two CW transmitters. It is this *adding* and *subtracting* that creates the rise and fall in the output signal of the transmitter, corresponding to amplitude modulation.

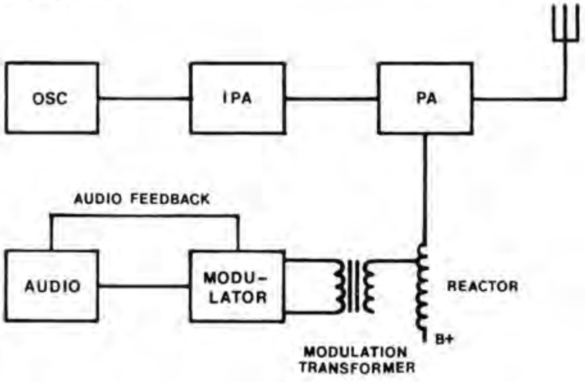


Fig. 1

Before we go into Ampliphase, let's quickly review the common method of producing amplitude modulation. The typical AM transmitter on the market today uses high level plate modulation (Fig. 1). In this transmitter, the plate voltage of the final power amplifier tube is made to vary at an audio rate. That audio rate is the speech or music fed to the power amplifier via the modulator tubes. The result is a waveshape coming out of the transmitter that varies in amplitude as a function of the transmitter's audio input — thus, amplitude modulation.

The big disadvantage however, is the high power audio circuitry needed to modulate the transmitter. In most cases, a modulation transformer is also required. This audio circuitry is the *weak link* of a high level plate modulated transmitter. Modulation at high levels requires a lot of audio power (at least 50 percent of the transmitter's rated power). Audio power is costly and inefficient. Besides, the modulation transformer limits the production of high quality modulation with low distortion. Ampliphase is a system of modulation in which no high power audio circuitry, or modulation transformer, or any other kind of audio transformer is used. As you will see, it is a truly unique way of producing amplitude modulation.

HOW AMPLIPHASE WORKS

Suppose we took two CW transmitters of 5 kW power, for example, and connected their RF outputs together (Fig. 2). If we operated them on the same frequency with their outputs *adding,* that is, in step or "in phase" with each other, we would get, at some point, a combined RF output of 10 kW. Of course, if

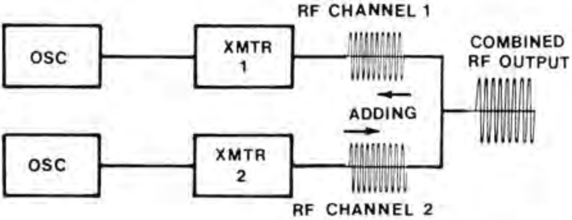


Fig. 2

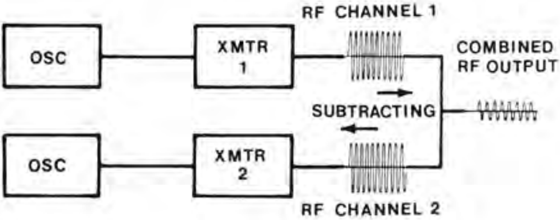


Fig. 3

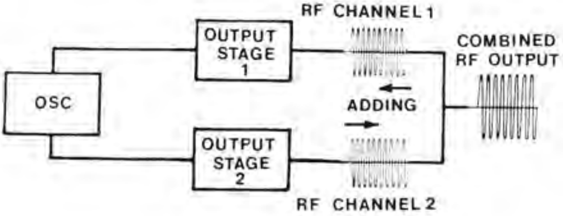


Fig. 4

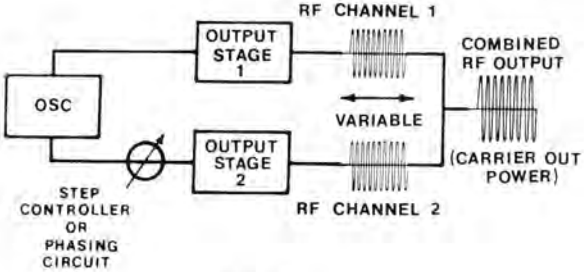


Fig. 5

transmitters 1 and 2 were out of step, or *subtracting,* the combined RF output would diminish, moving toward zero at the most extreme out of step condition (Fig. 3).

Now, suppose we derived our frequency from a single oscillator, and we made transmitters 1 and 2 the output stages of a 10 kW transmitter (Fig. 4). The above conditions would still apply.

Now, let's add a step controller or phasing circuit as a means of varying (adding or subtracting) the step or phase of one of the RF channels (Fig. 5). This will allow us to adjust the combined RF output to any value from zero to maximum power output. Now, since as in any transmitter we must have some level of carrier (transmitter output with no modulation), let's use our phasing circuit to arbitrarily set the phase of RF channels 1 and 2 so that they combine to give us an RF carrier power of 10 kW. We will use 135 electrical degrees of phase separation (Fig. 6) although it could be 140 or 145 degrees. Now that we have established our 10 kW carrier, all we need do to *modulate* our transmitter is to use our phasing circuit to vary the carrier at an audio rate between zero and maximum power output (in our case, 0 to 40 kW for 100 percent modulation).

How is this done? Let's apply an audio signal to the input of the phasing circuit — say 1,000 Hz. As the modulating audio sinewave starts to rise in the positive direction (Fig. 7), it will cause the phasing circuit to bring the two RF channels more in step with each other, and the carrier power will rise, reaching its peak at the top of the audio cycle.

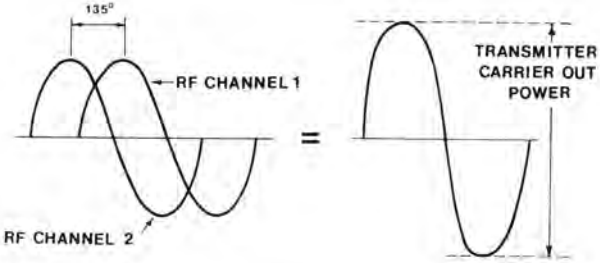


Fig. 6

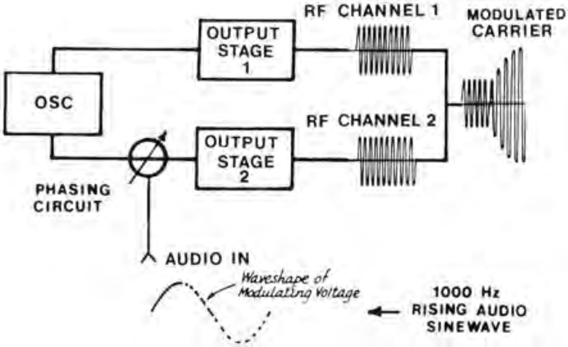


Fig. 7

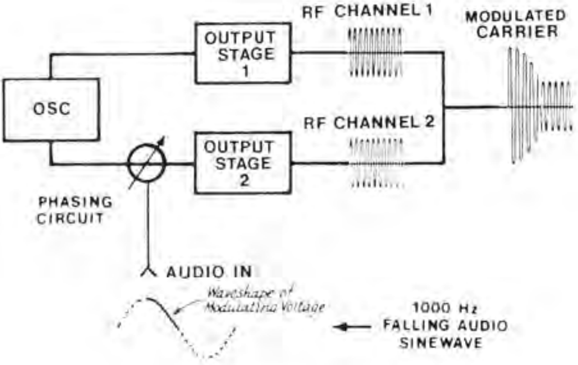


Fig. 8

As our 1,000 Hertz modulation sinewave falls in the negative direction (Fig. 8), it causes our phasing circuit to separate the two carriers so that they are more out of step.

The result is a drop in the amplitude of the carrier level, reaching a "modulation trough" at the down peak of the audio. Obviously, audio signals move a lot faster, but as they do, and no matter how complex they are, our phasing circuit (or phase modulator, as it is really known), continuously adjusts the phase of the two RF channels so that their combined output faithfully follows the audio input and provides us with amplitude modulation. That, basically, is the principle of Ampliphase.

Now that we know how it works, let's find out what it does for us.

WHAT ARE THE BENEFITS OF AMPLIPHASE?

To begin with, it has extremely wide frequency response. RCA Ampliphase transmitters are factory tested from 30 to 15,000 Hz, in a class with FM transmitters. This wide response is achieved in daily operation, not just in the factory or when new. In fact, Ampliphase transmitters will modulate from as low as 20 Hz, to more than 20,000 Hz. And they do it with very little distortion — less than 2 percent. Typically, the distortion is only 1.6 to 1.8 percent, even at audio frequencies as low as 30 Hz. What's more, operating costs are lower (each tube runs at

BTE-20A Solid State Ampliphase Exciter

Fig. 9

only 50 percent of its capacity, so it lasts longer). Then, too, you have the reliability of solid state circuitry right up to the power sections.

As every broadcaster knows, one criterion of a good transmitter is how it is put together. RCA Ampliphase scores high in this category, too, with its state-of-the-art circuitry and operator-oriented controls. The solid state exciter, heart of the Ampliphase system, is built around four plug-in modules. It is completely self contained and occupies only 5¼ inches of rack space. This same exciter is used in all RCA Ampliphase transmitters, from 5 kW up. Space is also provided in each transmitter for a standby exciter and changeover panel. A generous number of test points and completely accessible circuits throughout the transmitter make servicing and maintenance quick and easy. And when you are ready for remote control, your Ampliphase transmitter is ready too.

Finally, all RCA Ampliphase transmitters are capable of 125 percent modulation.

SECTION II
A TECHNICAL DESCRIPTION OF THE AMPLIPHASE SYSTEM

This section has been prepared for those interested in the technical aspects of Ampliphase. Operation of the unique phase modulator with its pulse techniques is described in detail, as well as the transmitter's super modulation capabilities. The use of high power class C amplifiers is covered with emphasis on the technical advantages of the pi combiner output network. Finally, this section documents the unmatched performance record of Ampliphase transmitters in frequency response, distortion, tube life and operating costs.

AMPLIPHASE CIRCUITRY

As we've said, the heart of every RCA Ampliphase transmitter is the BTE-20A solid state exciter-modulator (Fig. 9). The modulator is one of four modules that make up this compact unit. Then, there is the oscillator, drive regulator, and a power supply which furnishes regulated power to the other modules.

The drive regulator was our first step to further improve the Ampliphase circuit. This device works to increase the drive to the power amplifiers for higher positive peaks and to remove drive for clean negative troughs of modulation. Thus, with the aid of the drive regulator, we can achieve maximum negative modulation and extremely high positive modulation. Modulation on the positive half cycle in the order of 125 to 130 percent is easily reached and even higher values are possible. RCA has modulated an Ampliphase transmitter to almost 150 percent on positive peaks.

PHASE MODULATION FOR HI FI SOUND

You will note we said *exciter-modulator*. Applying modulation at low level is another advantage of Ampliphase as will be seen.

The modulator has two jobs. The first is to take the incoming audio and modulate the operating frequency in a process called phase modulation. This phase modulation, like in an FM transmitter, is what

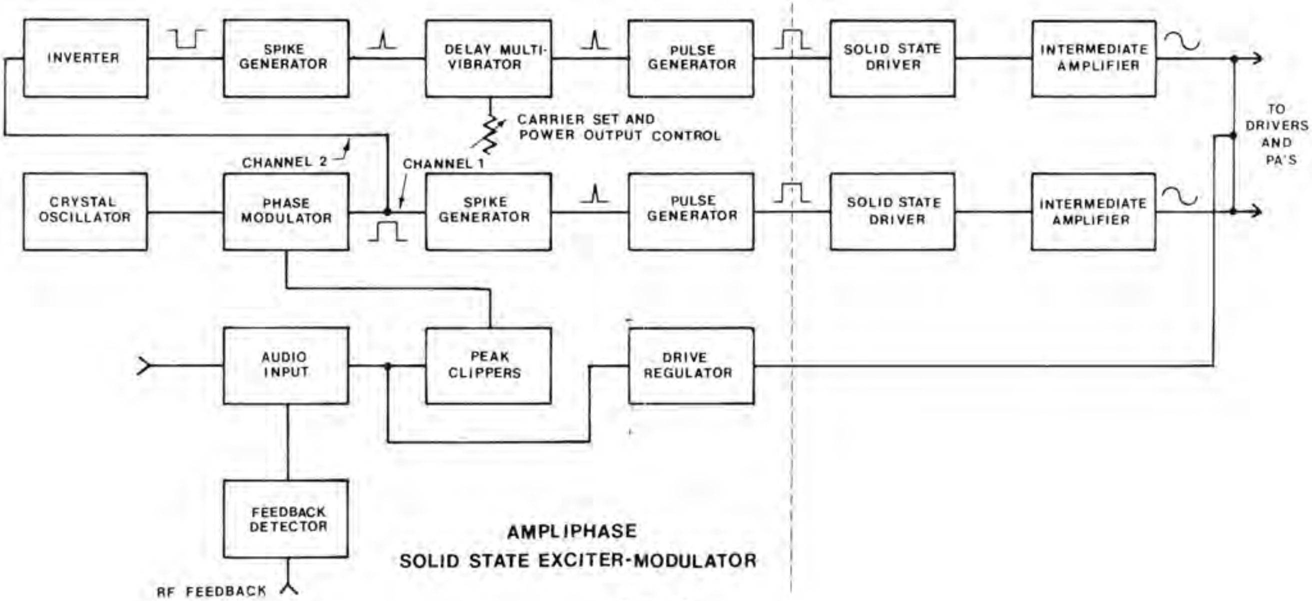


Fig. 10

gives Ampliphase its characteristic hi-fi sound. The other job is that of carrier power controller. This is the phasing circuit we spoke of which controls the phase relationship of the two carriers. As required by the incoming audio, the modulator actually controls the adding or subtracting of the two RF carriers.

Let's look at the operation of the BTE-20A in detail. The solid state exciter-modulator (Fig. 10) employs an unusual technique to provide the phase modulation required, while taking full advantage of modern integrated circuit technology. RF energy is first produced at the carrier frequency by a crystal controlled FET oscillator which in turn feeds the phase modulator.

The function of the phase modulator is to provide two channels of RF pulses that are phase modulated in opposition to each other. That is, while channel 1 is being advanced in phase, channel 2 is being retarded, or vice versa. The output of channel 1 leads the output of channel 2 by approximately 135 degrees at carrier. However, before going further, let us examine just how this is accomplished.

The sinewave from the crystal oscillator is converted into a square wave and then to a symmetrical triangular waveform. This waveform is combined with audio from the audio stages of the exciter in a zero axis detector to produce a pulse whose width varies according to modulation. Let's take a closer look at the zero axis detector to see how this is done.

During no modulation condition, (Fig. 11), the zero axis detector detects the crossing of the

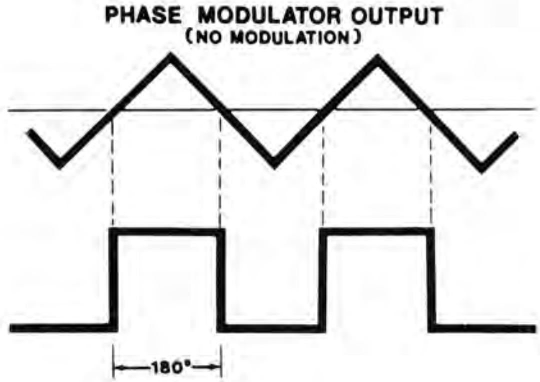


Fig. 11

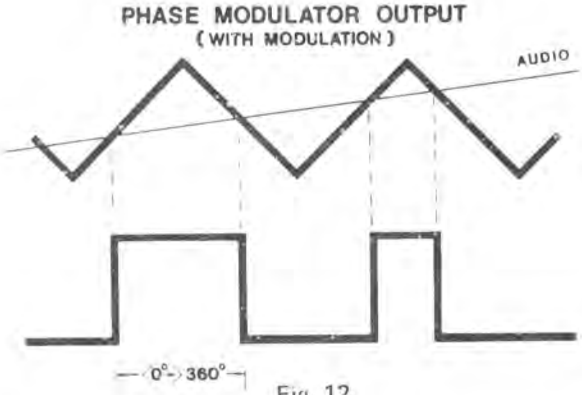
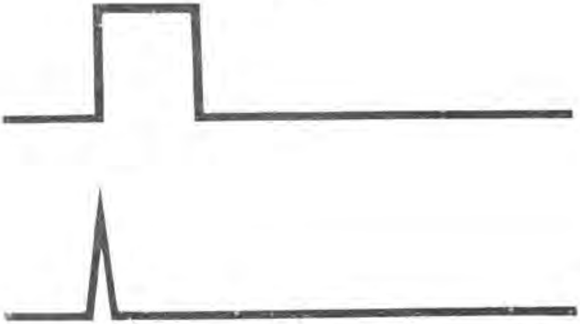


Fig. 12



CHANNEL 1

Fig. 13

symmetrical triangular waveform across its zero reference line and produces a symmetrical pulse whose width can be for example 180 degrees. Remember this is at the no modulation condition. During periods of modulation (Fig. 12), the reference of the zero axis detector is changed in direct relationship to the audio input. As you can see from this diagram, it produces a squarewave whose pulse varies in width from something greater than 0 to something less than 360 degrees.

FOOLPROOF PULSE WIDTH TECHNIQUES

It is important to remember that the output of the phase modulator is a single pulse whose width varies from something greater than 0 to something less than 360 degrees. This pulse width is determined by the amplitude of the audio signal.

The output of the phase modulator is split into two paths. We will call the lower path channel 1 and the upper path channel 2. The output of the phase modulator goes directly to the spike generator in channel 1. The second output from the phase modulator first passes through an inverter, inverting the squarewave pulse before being fed into the spike generator in channel 2. Let's examine these spikes in detail.

In the spike generator for channel 1 (Fig. 13), the leading edge or positive going portion of the squarewave pulse produces a spike at the output. As you remember, the channel 2 pulse was first inverted (Fig. 14) before its application to the spike generator. Again, the positive going portion (or trailing edge of the original pulse) is used to generate the spike. Thus, the output of the generators are two spikes whose phase relationship varies according to the modulation. The channel 2 spike is then fed to a delay multi-vibrator. This delay multi-vibrator does two things.

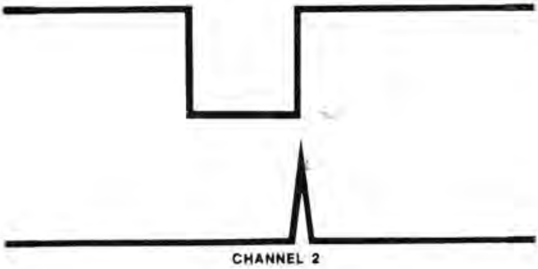


Fig. 14

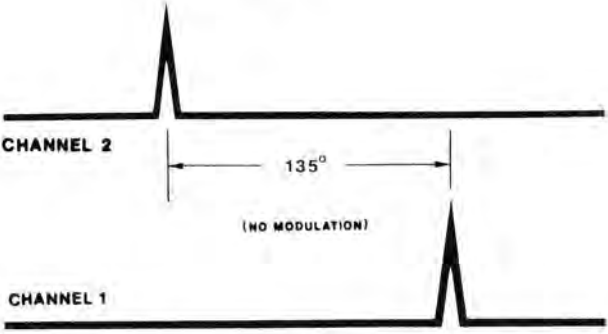


Fig. 15

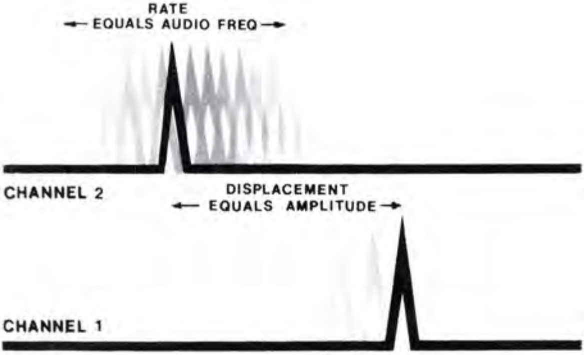


Fig. 16

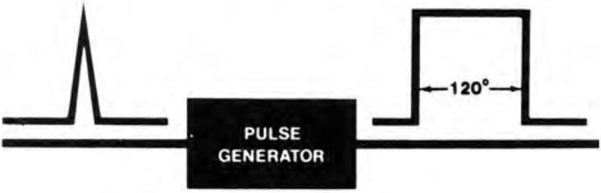


Fig. 17

First it allows us to delay the channel 1 spike. The delay then puts channel 1 ahead of channel 2 at the exciter output. This separation creates the necessary phase relationship between the two carriers. Nominally, it is 135 degrees, although some other value may be used (Fig. 15).

Secondly, it provides a means for making small changes in the phase relationship to produce small changes in power output. A control in the phase modulator allows us to adjust the transmitter to operate within the FCC specifications of +5 or -10 percent of the licensed power output. This can be accomplished by adjusting the phase angle between the two carriers manually or automatically by a feedback comparison circuit which controls the servo to a motor operated potentiometer.

When audio modulation is applied to the phase modulator, the outputs of the two generators (Fig.

16) are spikes varying in phase relationship with one another. This variation may be from 90 to 180 degrees, depending upon the instantaneous applied audio. The amount of displacement from the nominal 135-degree carrier condition is equivalent to the amplitude of the modulated waveform. The rate at which the two pulses are displaced from the nominal 135-degree carrier condition is equivalent to the frequency of the modulated waveform. These two spikes are fed to pulse generators (Fig. 17) in the solid state ampliphase exciter, whose width is nominally set at the factory for 120 degrees.

The output of the two pulse generators then feeds two solid state pulse amplifiers which are part of the basic transmitter. These stages amplify the pulse and feed the driver stages in medium power transmitters, and the intermediate power amplifiers in high power transmitters. In medium power transmitters, the driver stages are also the IPA stages. Either way, the function of the driver tube is to provide a combined amplitude and phase-modulated RF waveform to the grids of the power amplifiers. The two phase modulated signals are combined and converted into the amplitude modulated waveform across the common load resistance in the output circuit.

Let's take a moment to look at the operation of the audio circuitry in the solid state Ampliphase exciter (See Fig. 10). The audio input to the transmitter is fed into a differential amplifier. There are no transformers in the audio circuitry of the exciter. A feedback detector provides inverse feedback into the audio input circuitry and the amount of feedback is operator controlled from 0 to 6 dB.

Peak clippers prevent the audio input from exceeding preset positive and negative levels to insure correct operation of the phase modulator. An output is also taken from the audio input circuitry to the drive regulator. The drive regulator which is really nothing more than an audio amplifier, and its associated circuitry, provides voltage gain. The action is on the driver amplifiers to reduce drive during the negative half cycle of modulation and increase drive during the positive half cycle of modulation. The drive regulator is the key to producing clean negative peaks and increased positive peaks of modulation.

The output of the drive regulator in the lower power Ampliphase transmitters is fed to the pulse amplifiers where it is superimposed upon the DC drive control voltage. This causes the positive excursions of the rectangular RF waveform to vary in accordance with the audio signal supplied by the drive regulator. In the high power Ampliphase transmitters, drive control voltage is used to vary the bias at an audio rate in the driver tubes.

HIGH POWER CLASS C AMPLIFIERS

Thus, the Ampliphase system is basically two parallel continuous wave transmitters using the solid state exciter previously described, and conventional class C amplifiers with their inherent high efficiency as the final power amplifiers. Plate voltages on the two power amplifier tubes are constant throughout the modulation cycle. The radio frequency energy is amplified by conventional means through the output end of the two high powered amplification channels, where another key to the success of the Ampliphase system lies (Fig. 18).

SIMPLE PI COMBINER OUTPUT

This key is the combining network across which the modulation is formed. Surprisingly enough, it is a very basic circuit made up of two 90-degree pi networks coupling each power amplifier to the common load. If the RF energy from the two power amplifiers is fed in phase, the network acts as a single

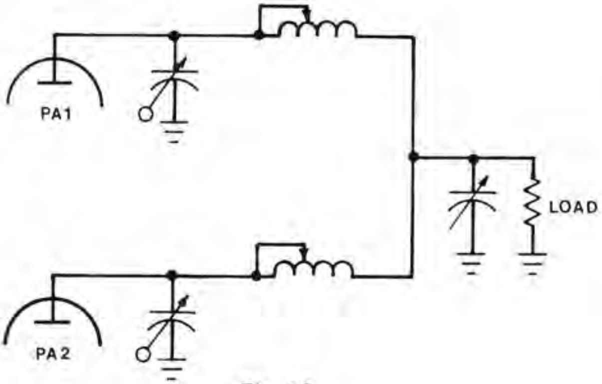


Fig. 18

paralleling device to couple the two amplifiers to the single load. The feeding of the two signals to the network in an out-of-phase condition produces less voltage at the output than the in-phase condition. Further, since the impedance at the output of the combining network changes in the out-of-phase case, the network no longer appears as a tuned load to the power amplifiers. To provide resistive loads for the power tubes, the input element of each 90-degree network is adjusted accordingly. The pi network capacitor in the power amplifier experiencing inductive reactance is increased to draw more capacitive current from the amplifier thereby compensating and providing the real load required for efficient amplifier operation.

Likewise, in the power amplifier experiencing capacitive reactance, the input element is adjusted to an equal amount in the opposite direction to provide the amplifier with a purely resistive load at carrier level.

The characteristics of this combining network offer some very definite operating advantages over other transmitter systems. One is that a change in load reactance *does not* detune the amplifier stages to any great extent, but serves only to adjust the proportion of the power contributed by each stage. The power delivered to the load of the system changes very little over wide ranges of reactance values. This advantage is of great importance when the antenna load has highly reactive sideband impedances. The reason is that modulation linearity and efficiency are not greatly affected and the output capability is not limited by a condition of high reactance at the sidebands.

FREQUENCY RESPONSE LIKE FM

One of the immediately noticeable results of this modulation technique is the extremely wide frequency response. Since the actual modulation process is phase modulation and is not limited because of transformers, frequency response in the order of 20 to 20,000 Hertz is not unusual (Fig. 19). In fact, RCA has measured a BTA-50J (50 kW Ampliphase transmitter) to 30,000 Hertz. In Meadow Lands, Pennsylvania, where the RCA trans-

MEASURED FREQUENCY RESPONSE

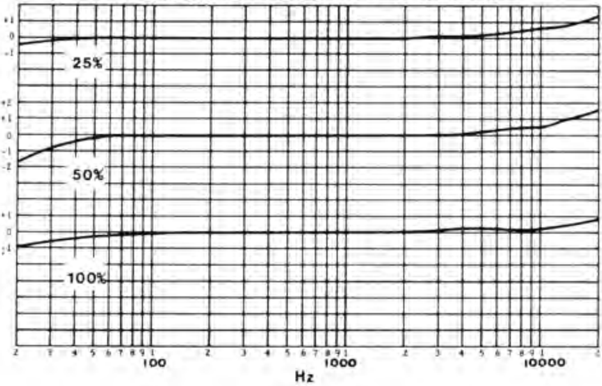


Fig. 19

mitters are built, it is part of the normal test process to measure audio frequency response from 30 to 15,000 Hertz – just like an FM transmitter.

While RCA specifies a frequency response of 1.5 dB from 30 to 15,000 Hertz, Ampliphase transmitters typically average within 0.8 dB from 30 to 15,000 Hertz and at distortions of less than 2 percent.

LOWEST DISTORTION

While we're on the subject of distortion, another important feature of Ampliphase is the low percentage of audio distortion. A contributing factor to distortion in any audio system is transformers. In AM, that transformer is an audio input transformer and a modulation transformer. Keeping audio distortion to a minimum is a function of the amount of iron used in the transformer. The more iron, the less distortion. Most audio transformers exhibit their greatest distortion and, by the way, their poorest frequency response, at the low end of the audio band. We said most transformers because it is possible to design a low distortion wide band audio transformer. However, this too has limiting factors such as size and cost.

Where we are dealing with milliwatts or watts of audio power, a transformer exhibiting low distortion and wide frequency response can be produced. In AM transmitters, however, we are dealing with kilowatts of audio power and this becomes a problem – both from size and cost to the transmitter manufacturer. Please bear in mind it takes about 25,000 audio watts to plate modulate a conventional 50 kW AM transmitter. Thus it can readily be seen why the modulation transformers should be eliminated. RCA Ampliphase transmitters have no audio transformers of any kind!

The Ampliphase system contributes very little audio distortion to the program material. While RCA specifies a maximum of 2 percent audio frequency distortion, typically, the numbers are a lot less (Fig. 20). Averaging of the actual measurements taken from factory test data shows that RCA Ampliphase transmitters exhibit audio distortion of less than one percent. That's something really hard to match by any other system of transmitter modulation – even FM!

LOWER OPERATING COSTS

The Ampliphase system also contributes to longer tube life which means lower operating costs. In an Ampliphase transmitter, each power amplifier tube is operating at only 50% of its rated power. Therefore, its reasonable to expect longer than average tube life. Some Ampliphase transmitters have power amplifier tubes with 50,000 operating hours. This is not unusual and applies to all Ampliphase transmitters regardless of power.

BEST TRANSMITTER INVESTMENT

Many methods of modulation have evolved and new ones have been proposed. RCA has considered

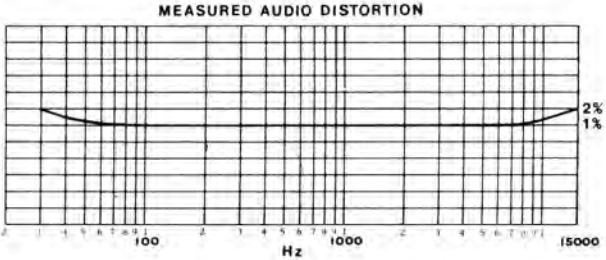


Fig. 20

them all, for actually, even the "new" have been around for a while. In common, they all possess drawbacks which deter from the overall performance of the transmitter.

Ampliphase with its wide frequency response, low distortion and great economy of operation easily outperforms the ordinary 5-, 10-, 50-kW, and even the higher power AM transmitters. We believe it represents the best transmitter investment a broadcaster can make — both in terms of engineering and in terms of dollars spent.

And what else is there to look for in a broadcast transmitter.

For further information or planning assistance on Audio/Radio equipment and systems, contact your RCA Representative. He will be glad to share his experience with you.

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