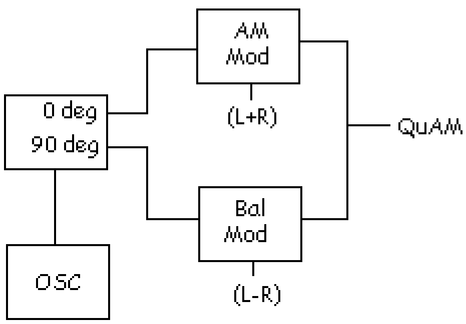
Alternate Methods of Generating (C-)QuAM

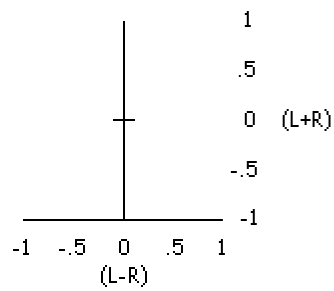
Preface; The author has been interested in AM Stereo broadcast for many years. Following the FCC decisions regarding an appropriate system for stereophonic AM broadcasting and reception, he has decided to put to rest his own opinions regarding the subject. With this in mind, he has decided to embrace a journey through the Motorola corporation's Compatable Quadrature AM system. This paper (the first in a series), is to illustrate a couple of alternate methods for generating the QuAM signal. These schemes do not require an (L-R) matrix in their operation.

Motorola C-QuAM(R) Redux

C-QuAM(R) is a modulation scheme by which a stereo QuAM signal is fed through a limiter, producing a pseudo-phase modulation RF signal which is used to excite an AM transmitter. The (L+R) signal is also fed to the audio input of this transmitter. The simple QuAM signal is limited because of the distortions produced by single channel or (L-R) modulation. The best illustration of this is in the case of (L-R) only modulation.

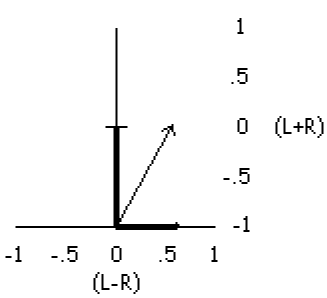


Block diagram of simple QuAM transmitter

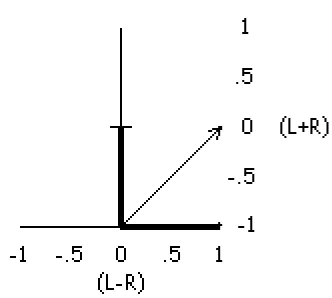


Vector chart of simple QuAM

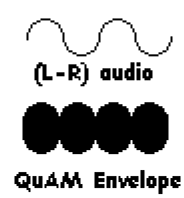
The following diagrams illustrate what happens if we do exactly that- transmit just a difference (L-R) signal and nothing in the monaural (L+R) channel using simple QuAM. What may not be appearant at first is the vector addition taking place as the (L-R) axis modulates against the (L+R) carrier. Mathematically, with 100% modulation on the (L-R) axis and 0% (L+R), this resultant vector is 1.41 times what it was at 0% modulation of all channels. The third diagram shows what happens at the QuAM output under this condition. A monaural receiver using a simple envelope detector will be producing a highly distorted 2nd harmonic of (L-R) at a time when it's speaker should be quiet!



Vector of 50% +(L-R)



Vector of 100% +(L-R)

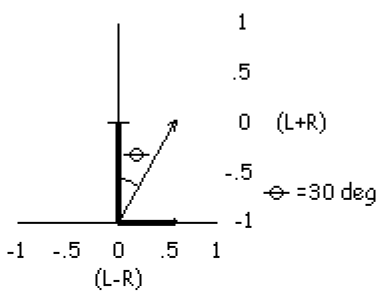


Effects of (L-R) only on simple QuAM signal

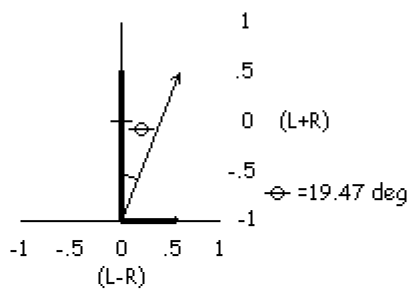
The C-QuAM signal is also fitted with a pilot signal of 25 CPS to the (L-R) channel to indicate to the receiver the presence of a stereophonic broadcast.

A "what if" (sensless ponderings)

Since modulating (L-R) while leaving (L+R) unmodulated renders a phase modulation in the carrier, and modulating (L+R) only renders no phase modulation, we could consider using just the (L-R) component to phase modulate the carrier and ignore (L+R) for the composite transmitter excitation. To be sure, the Magnavox system utilized phase modulation from (L-R) only. However another look at the vectors shows this would not render a true QuAM signal, at least where the angles are concerned. In this example, we'll use 100% left channel upward modulation. Remember, if 100% (L+R) or (L-R)=1, then single channel 100% modulation renders .5 in each axis.



Ignoring (L+R) contribution



Including (L+R) contribution

If we were to take a look at downward modulation in the example, we would notice the phases are again 30 deg for the (L+R) ignored condition, and 45 deg for the included condition. Therefore the (L+R) component must be included for there to be a true QuAM signal. Furthermore, the (L+R) signal is necessary for properly extracting the (L-R) signal from C-QuAM at the receiver.

Some radio history

1935 must have been a banner year in the world of radio. In France, Henry Chierix developed a method for generating an AM signal from 2 phase modulated RF signals. He called his scheme "outphasing". In the United States, Edwin Armstrong demonstrated his wide-band FM transmission system. Chierix's work bore fruit in the late 1950's, and carried on into the early 1970's. It is today known among a group of broadcast engineers and radio fans. Armstrong's contribution however, is better known by the public at large.

Radios or rabbits?

Armstrong's FM signal started from a phase modulator exhibiting a very small deviation. Thus many stages of frequency multiplication were required to get the desired carrier swing. Using the example in M.S. Kiver's "FM Simplified", our 200 KC phase modulated signal from the modulator has a net deviation of 25 CPS. The chain this signal goes through procedes thus.

MC Freq	.4		1.2		3.6		10.8	32.4
		X2		X3		X3	X3	
KC Dev.	.025		.05		.45		1.35	4.05

At this point the signal is "beaten back". While the carrier is decreased in frequency, the net deviation remain unchanged. In other words, 'the signal you are hearing is true. Only the carrier has been changed to protect the swing.' This is necessary, else for 75 KC deviation, the carrier would wind up over 500 MC. Definitely out of band and not ready for post WWII state of the art consumer gear.

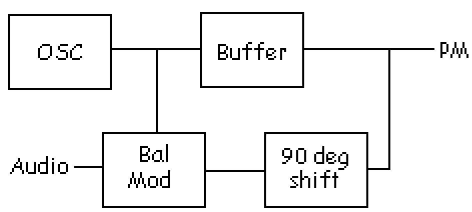
Mixing with 27 MC renders,

MC Freq	5		15		45		90
		X3		X3		X2	
KC Dev.	4.05		12.15		36.45		72.9

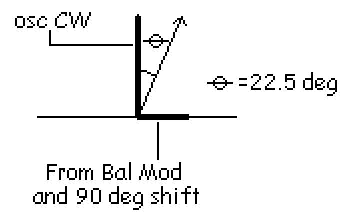
Here we can see a net multiplication of 972, along with the "beat back" required produce the desired deviation. It is interesting also to note the next to the last step in this process, having some knowledge of the history of the 45 MC FM broadcast band.

PM from AM

The phase modulator used by Armstrong for his system (and necessitating much multiplication), is quite interesting and deserves a look for the purposes of this paper.



Block diagram of Armstrong's phase modulator



Vector diagram of Armstrong's phase modulator

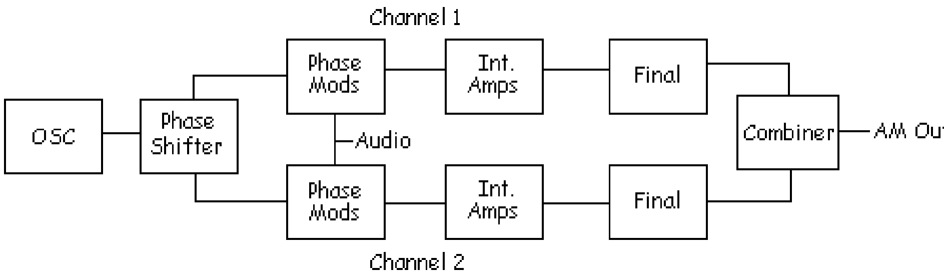
Since a balanced modulator is an AM modulator with the carrier nulled out, we are indeed able to derrive a PM signal from AM using this method. The AM present in the resultant vector was removed in Armstrong's transmitter with the numerous frequency multipliers used.

Victor's vectors

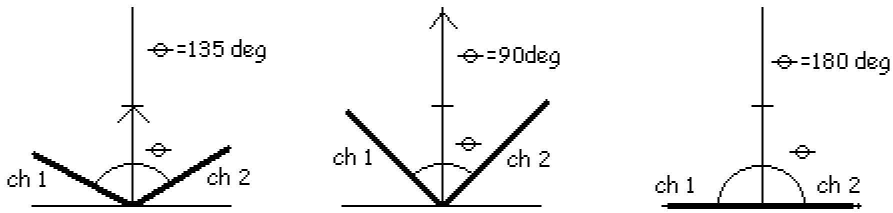
In 1955, the RCA introduced a broadcast transmitter utilizing H. Chierix's outphasing modulation technique mentioned earlier. This develops an AM signal from 2 phase modulated transmitters, tied together at their tail ends. The phase modulators are connected such that on modulation, one phase advances while the other retards. The chosen phase difference for an unmodulated carrier is 135 deg. Thus for 100% upward modulation, the difference is 90 deg, and for 100% downward, 180 deg. If we choose a phase difference of 90 deg for unmodulated carrier, we experience a compressed envelope as the modulation approaches 100% upward.

The "Ampliphase" as the transmitter came to be known, made possible a true high fidelity, high power transmitter. An added bonus was the increased effiency of the transmitter, made possible in part by not having to use a high power audio amplifier feeding the final stage. Since some of the adjustments of the transmitter can be a bit tricky, it has earned the nickname "amplifuzz" by some harried engineers. However, a properly adjusted Ampliphase is capable of astonishing audio performance, even by today's standards. Because of this, the design was very popular for many years, and interest in the transmitter continues to this day.

Below are the diagrams and vectors (sigh) describing the operation of this transmitter.



Basic block diagram of the RCA Ampliphase transmitter

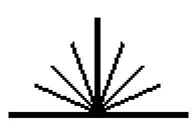


Vector operation of RCA Ampliphase transmitter

If you will notice the rays describing the channel 1 and 2 outputs are longer in the 100% upward example, you are not alone.Most of this contribution comes from how the signals join in the combiner, another part of this "lengthening" comes from the drive regulator. The regulator (not shown in the block) provides a bit of "bistromath" to the RF levels based on audio to improve linearity and efficiency of the overall transmitter.

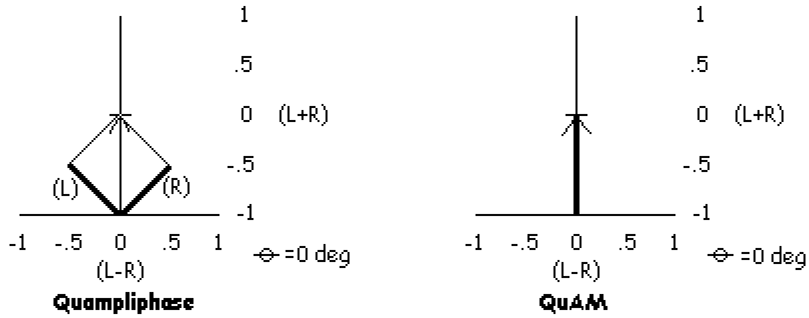
AM, PM, QuAM, and other members of radio's alphabet soup

It occured to the author of this paper that the idea of generating a C-QuAM signal using a derrivative of the outphasing technique might be a valid one. It was hoped to be able to generate the entire C-QuAM signal via this technique. However, we still have to deal with the linearity problems on (L-R) using the Armstrong modulator unlimited as in the QuAM example at the begining of this paper, and linearity problems in (L+R) with the carriers in quadrature if we limit the modulators as in the Ampliphase example. The eventual solution to this techno-mathematical puzzle lies in using the Armstrong modulators, in quadrature and without limiting. The outputs of the modulators are added algebraically, and then sent to the limiter, class C RF amplifiers, et al. The really neat thing about this is that no (L-R) matrix is required- left channel feeds one modulator, right channel feeds the other. The only thing remaining is to add a pilot signal, antiphase to both modulators. The author has called this technique "Quampliphase", and also has developed a symbol to describe the phasors in its operation.

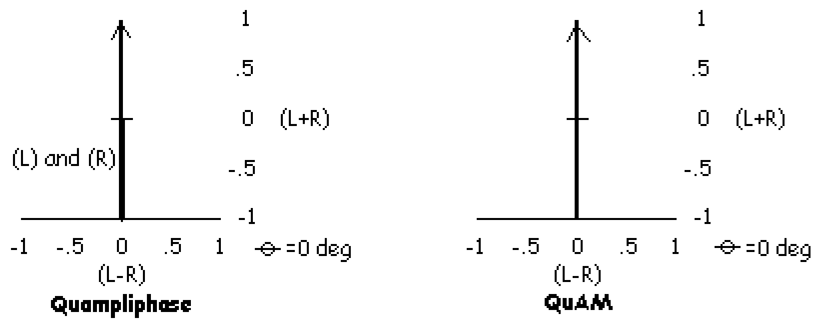


QUAMPLIPHASE

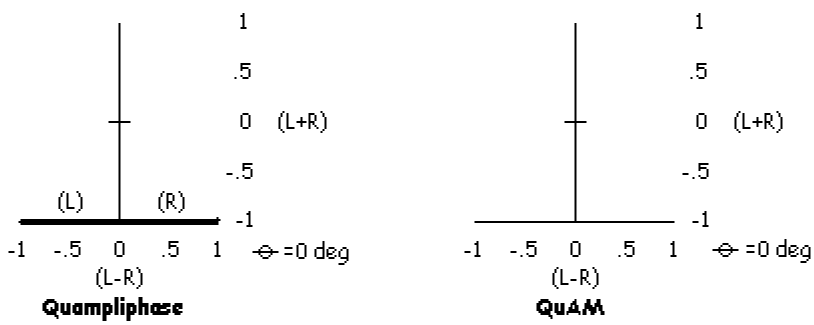
In short, the premise behind Quampliphase is the use of 2 Armstrong phase modulators, in quadrature to generate the QuAM signal. With that in mind, let's take a look at the comparisons between ordinary QuAM and Quampliphase. Again, if (L+R) or (L-R)=1, then (L) or (R) only is 0.5.



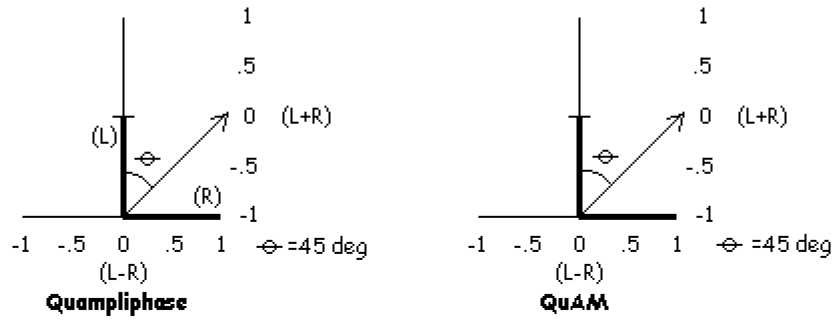
Condition of no modulation, any channel



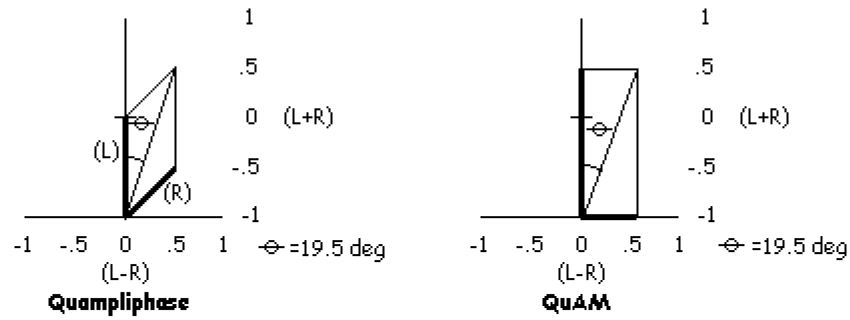
Condition of 100% upward, both (L) and (R) in phase



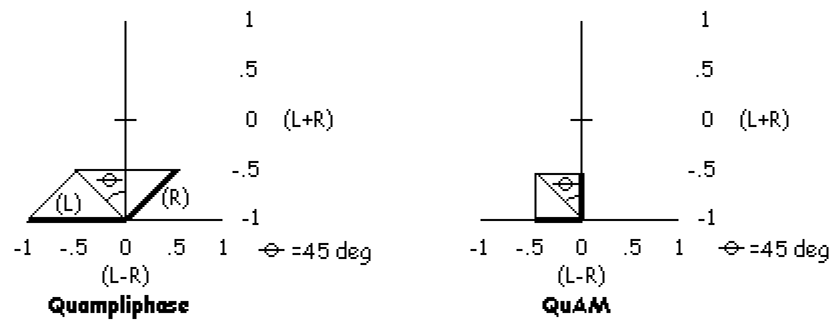
Condition of 100% downward, both (L) and (R) in phase



Condition of 100% upward, both (L) and (R) antiphase

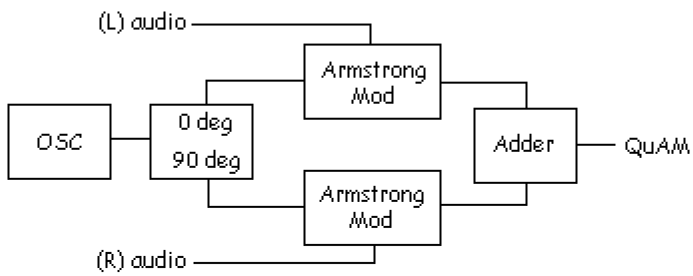


Condition of 100% upward, (L) channel only



Condition of 100% downward, (L) channel only

As we can see here, the resultant of the Quampliphase signal mimics that of simple QuAM. Of course it can be assumed in the case of the single channel examples, the (R) channel will have the same phase deflection for the same direction of modulation, but the direction of the deflection will be reversed. A block diagram for the Quampliphase generator is shown below.

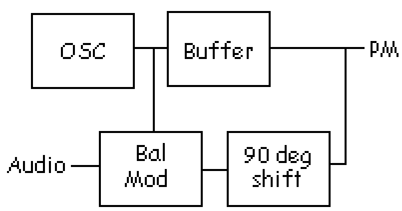


Block diagram of Quampliphase stereo QuAM generator

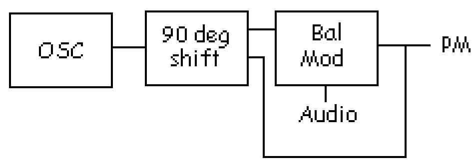
The 90 deg phasing network can be any suitable method for generating quadrature, be it a primary/secondary tuned circuit, an R/C network, or OSC=4F into a Johnson counter.

The 2AM thing works!

A closer look at the scheme reveals that the 2 Armstrong modulators could just as easily 2 AM modulators in quadrature. Redrawing the circuit and expanding the Armstrong modulators we can see that the carrier for the left channel is provided by the quadrature carrier feeding the right channel. This is reminiscent of the picture that could be a vase or 2 faces.

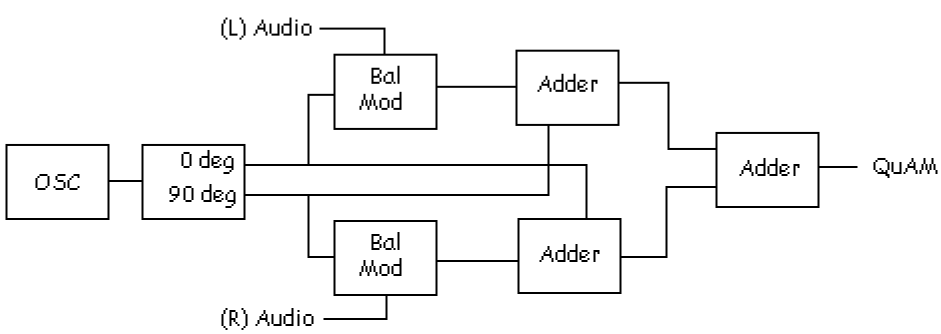


Block diagram of Armstrong's phase modulator



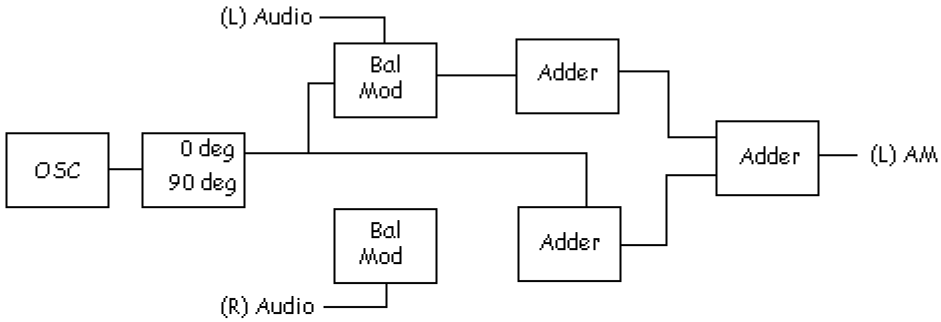
Redrawn for Quampliphase

And expanding this to the whole Quampliphase circuit we have,



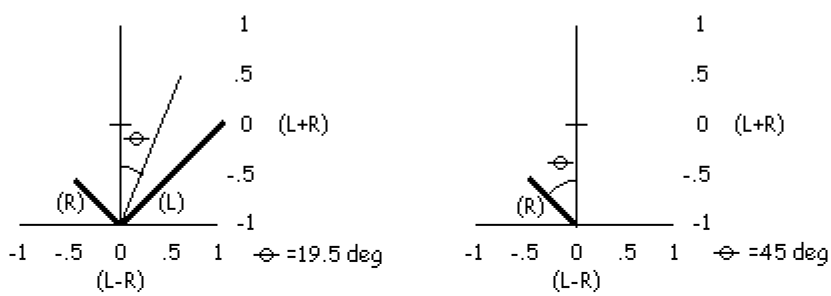
Quampliphase, all components shown

Then simplifying for (L) channel only,



Quampliphase, left channel only

Here we can see that the carrier that adds to the (R) channel balanced modulator provides an in phase carrier for the (L) channel balanced modulator, and same vice versa. Rather than go through a whole new series of vectors, we'll use the 100% upward and downward (L) channel only examples. Compare these to the earlier vectors comparing Quampliphase and QuAM.



(L) channel, 100% upward **(L) channel, 100% downward**

2AM vector diagrams, (L) channel only

Note the vector assignments for the 2 channels are reversed compaired to the earlier schemes. It was at first considered calling the 2 AM modulator scheme "Dual Amplitude Modulation" except the abbreviation was feared to insult some people's sensibilities. To this end, the moniker 2AM, pronounced "tomb" was decided upon, evidence the title of this section. This also works on yet another level when you consider the upper case cursive letter "Q" resembles a number 2.

Semantics aside, what we wind up with here via 2AM is a somewhat simpler method for generating the QuAM signal. This could be a basis for another method for a part 15 transmitter.

Coda

This is an ongoing work, and further developments may be shared with the group as time, family, work, and other hobbies permit.

John W. Hausback
Rough draft June 15th, 2003 @ 0409 CDT
Final draft July 7th, 2003 @ 2109 CDT
Edit to PDF July 9th @ 0015 CDT

To be continued...

Bibliography

Introduction To The Motorola C-QUAM AM Stereo System,
C. Payne, et al

FM Simplified,
M. S. Kiver

The Ampliphase Page,
www.rossrevenge.co.uk

Ampliphase... For Economical Super-Power AM Transmitters,
D.R. Munson

AM Stereo- An FCC Fiasco,
L. Feldman

Life, The Universe And Everything,
D. Adams