CONTROLLED CARRIER MODULATION

Controlled carrier modulation is to the RF end of a modern transmitter what class B is to the audio end. In addition to the advantages of increased power efficiency, extended tube life and the use of smaller tubes for high power output, controlled carrier modulation reduces interference between stations and increases effective working range of transmission.

The data and explanations which follow will readily substantiate these facts to those who are interested in the theoretical side of transmitter design.

Controlled carrier modulation can be defined as a method of modulation in which the average carrier output varies with the audio level, instead of remaining constant as in conventional modulation systems. Fig. 1 illustrates the relation of RF power to AF power in a typical transmitter using the

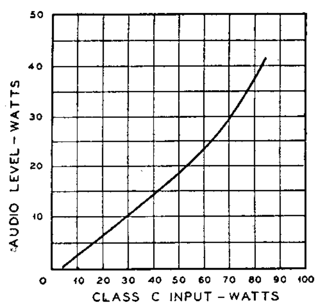

FIG. 1—Class C input vs. Audio level in a Controlled Carrier Transmitter.

first really practical system of controlled carrier modulation. This experimental transmitter used four 59s in class B in the audio modulator and a pair of 801s with controlled class C input in the final. Before going into the technical details of this transmitter, let us examine more closely the various advantages of this controlled carrier modulation and the effects which produce these advantages. They can be enumerated as follows:

1. Reduction in Power Consumption and Operating Costs.

Fig. 2 illustrates the relationship of power measured at the primary of the plate transformer for the final as compared to different audio levels. Every amateur who has watched the wiggling of the plate current meter in a class B amplifier, or by means of an oscillograph used to check percentage modulation, realizes that speech and music are not of continuous level, but consist of a series of valleys and peaks representing different audio levels. Tests by the writer have indicated that if these valleys and peaks are integrated over a period of time, the average audio output is less than 20 per cent of the amplifier peak power handling ability. This is particularly true of the amateur phone station, because silent periods of short duration are extremely frequent. An approximate check taken on three stations indicated that the effective audio power was less than 10 per cent of maximum for 90 per cent of the time.

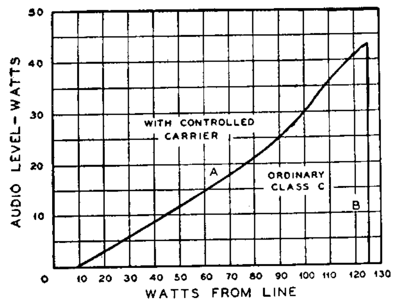

FIG. 2—Comparison Between Ordinary Class C and Controlled Carrier Class C as Referred to the Variation of Power Consumption from the Line vs. Audio Power.

Using this approximate check, the audio power taken 90 per cent of the time on the transmitter described above would be below $4\frac{1}{2}$ watts. In an ordinary transmitter using 801s for the final, Curve B, Fig. 2 would indicate that a constant power of 125 watts would be taken from the line by the final plate transformer. Considering this with respect to Curve A, Fig. 2, this means that for 90 per cent of the time the power taken from the line will be reduced to less than 24 watts. Furthermore, for a very considerable portion of the time the power taken from the line by the final plates will be only 10 watts. This saving in power is tremendous. If duplex operation is used, the operating cost is reduced still further, as negligible plate power is taken by the final during receiving periods.

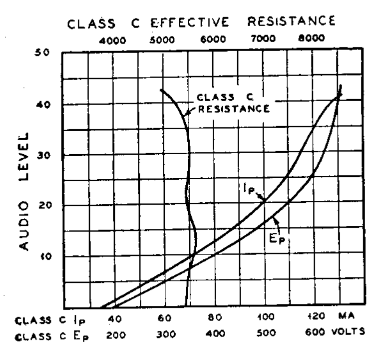

FIG. 3—Relation of Class C Operating Characteristics to Modulator Level in Controlled Carrier Transmitter.

2. Increase in Tube Life.

Referring again to Fig. 1, it is seen that at low audio levels the class C input is very low. This is shown still more clearly in Fig. 3. It is seen from this latter curve that at zero audio input the class C plate current is only 36 milliamperes total, and the corresponding plate voltage 195 volts. The increased tube life at this low plate power is obvious. Using the previous approximation of 10 per cent audio level for 90 per cent of the time, the class C input to this pair of 801s is found to be less than 15 per cent its maximum value for most of the time. The resultant reduction in plate dissipation should increase the tube life many times over. At the moment, the writer does not have facilities to determine this increase and we must consequently wait for further data from the tube companies before an accurate measure of this replacement economy can be determined.

3. Use of Smaller Tubes for High Output.

Most amateurs are familiar with the theory of class B amplification and realize why class B audio amplification made possible greater power from audio tubes. This is easily seen on the curve for plate current vs. power output of a class B system as in Fig. 4. Because the plate current swings through a wide range, the average effective plate current is much less than that at maximum output. An examination of Fig. 3 will show a striking similarity between the class C plate current vs. audio level and the class B plate current vs. audio level of Fig. 4. The effect of the curves is almost identical and consequently it is found that the available power output from a given pair of tubes used with controlled carrier modulation can be increased greatly over the output available from the same tubes in a normal class C amplifier. Tests conducted so far seem to indicate that an increase of almost 100 per cent can be obtained.

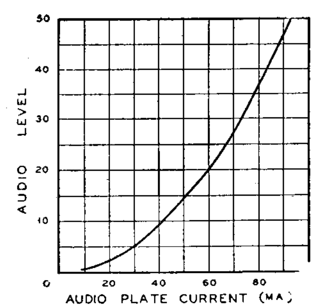

FIG. 4—Relation of Plate Current to Watts in a Typical Class B Amplifier.

4. Reduction of QRM

Because the carrier magnitude is reduced for the greater part of the time, interference between stations is greatly reduced. This is of vital importance in broadcasting as the allocation of stations by the FCC is such that normal interference is comparatively small. The additional aid of reduction in carrier would eliminate this effect practically entirely. To the amateur this is of importance, using controlled carrier modulation the beat note between stations is reduced for a major part of the time.

5. Increased Working Range.

One of the first fundamentals in phone transmission is the formula which states that the carrier power required for a given field coverage varies inversely as the square of the modulation percentage. Assuming for ordinary speech a percentage modulation of 10 per cent for 90 per cent of the time, we find the following peculiar fact; since

$$\frac{\text{Power A}}{\text{Power B}} = \frac{\%\ B^2}{\%\ A^2}$$

and assuming 50% for "A" (controlled carrier) and 1.58% for "B" (regular class C): (See Fig. 8):

$$\frac{\text{Power A}}{\text{Power B}} = \frac{.25}{.00025} = 1000$$

This means that at 10 per cent audio level the same coverage (distance) could be obtained from a 10 watt transmitter using controlled carrier as from a very much larger transmitter using normal class C. This does not apply to the maximum audio level; at which well-designed transmitters of both types should give 100 per cent modulation. However, as previously stated, the average audio power is far below the maximum audio power. In this respect it might be remembered that broadcast stations have found that the minimum audio power range for good fidelity must be at least 30 DB. This represents a minimum audio power equal to .1% maximum audio power which is a much greater change in percentage modulation in the ordinary transmitter than in any of the examples referred to above.

6. Increased Fidelity.

Broadcast stations have found it necessary to increase the range of audio levels they transmit very appreciably to take care of modern high fidelity requirements. Massa of R.C.A. claims that a range of 70 DB. in audio level is required for real high fidelity. One of the greatest stumbling blocks in the progress of broadcasting in this respect has been the fact that due to the decrease in modulation percentage, the corresponding effective coverage is reduced in accordance with a square law. However, using controlled carrier modulation, the major part of this effect can be eliminated and a much greater range in audio level can be obtained with the same maximum power output and the same coverage. Another important factor in fidelity is the tendency prevalent among broadcast stations and amateurs to overmodulate. If controlled carrier modulation is used, when the audio

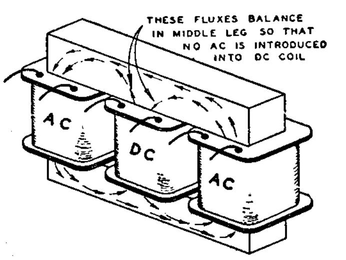

FIG. 5—Appearance of Saturable Reactor

level rises to the point of normal overmodulation, the class C input is automatically increased sufficiently to minimize the effect.

Circuit Details

The basis for control in variactor controlled carrier modulation is the fact that as shown in Fig. 4 the plate current in a Class B audio amplifier varies practically linearly with the power output. The plate current is used to saturate a control reactor which in turn controls the plate supply of the class C final. If a class A modulator is used, other means of obtaining this control current are possible. Fig. 5 illustrates the general nature of a saturable reactor. A shell type laminated core of somewhat different proportions than that in an ordinary transformer is used for the magnetic circuit. Three coils are placed on the respective legs of this core, the outer two being connected in series with the AC line and so related in polarity that their respective magnetic fluxes are in accordance with the arrows shown. It is seen that the MMFs of the two AC magnetic circuits are opposite in direction in the middle leg and tend to neutralize each other. If the coils and magnetic circuit are perfectly balanced, these fluxes will be perfectly balanced and no AC flux will traverse the middle leg of the laminations. The control coil is placed on this middle leg and the plate current of the Class B modulator is passed through it. All radio men are familiar with the fact that as the DC current is increased in a filter choke, its inductance decreases. Exactly the same effect is produced here, except that by proper design a fairly linear relation and a wide range in inductance can be obtained.

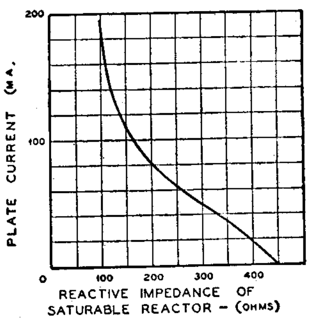

FIG. 6—This Curve Shows the Change in Reactance of AC Coils in a Saturable Reactor as the DC is Increased.

Fig. 6 illustrates this relation of saturating DC to AC impedance in the experimental reactor used in the transmitter previously referred to. The linearity of this curve is increased still further in the larger variactors.

The saturable reactor is placed in series with the primary of the final plate transformer. It is seen from Fig. 6 that with no audio signal (minimum DC) the reactance of this reactor is quite high (450 ohms). This effects a great voltage drop to the primary of the plate transformer, as the effective impedance of this primary is quite low. However, as the saturating DC is increased, the reactance is decreased, and the consequent voltage drop is decreased. The primary voltage rises in accordance with this, and with proper design, reaches almost maximum at normal maximum audio output. Even with the reactor practically saturated, a small reactance and consequent voltage drop exists. To compensate for this, an autotransformer is used on the line side of the reactor which increases the total impressed voltage. This autotransformer does not have to be used if the plate transformer primary is wound or tapped for the reduced voltage obtained after the reactor drop. In either case, this voltage drop does not represent a power or efficiency loss, as the drop is almost entirely reactive and results primarily in a change of power factor; i.e., the ratio of VA/watts increases only.

It is apparent, on examining the circuit of Fig. 7, which shows a typical application of this reactor type controlled carrier modulation to an already existing transmitter, that the actual alterations necessary are quite small. Except for the autotransformer-reactor combination and a non-critical condenser, 1 to 8 Mfd., (if it is not already present in the modulator) no additional equipment is necessary. The circuit changes are extremely simple. The DC coil of the reactor is connected in series with the B plus lead of the

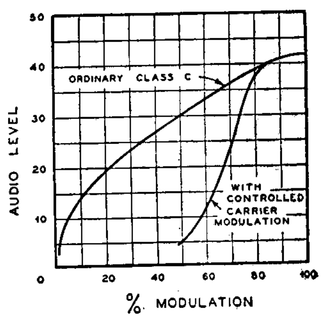

FIG. 8—Percentage of Modulation in Ordinary and Controlled Carrier Transmitters at Various Audio Levels.

modulator. The autotransformer primary is connected to the line and the primary of the class C plate transformer is connected across the output side of the autotransformer with the AC coils of the reactor in series. That is all there is to obtaining controlled carrier modulation from an existing transmitter. A simple switch as indicated in Fig. 7 permits instantaneous changeover from standard to controlled carrier.

We could write pages of superlatives about UTC variactor controlled carrier modulation but we suggest instead that you "ask the man who owns one."

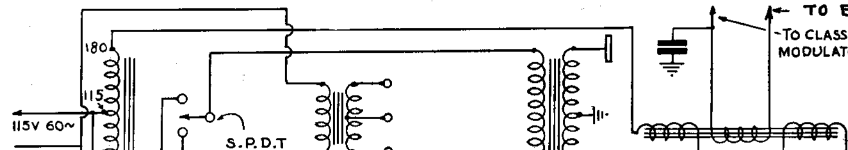

FIG. 7—Circuit of Controlled Carrier Transmitter.

UTC TRANSMITTING POWER SUPPLY COMPONENTS

PLATE TRANSFORMERS

Primary 105, 115, 220, 230 volts A.C. 50/60 cycles

PA-110	515 or 625 each side of center at 200 MA 400 VDC or 500 VDC. PA-3	**$10.00**
PA-111	750 or 900 each side of center at 250 MA 600 VDC or 730 VDC. PA-4	**18.00**
PA-112	1250 or 1400 each side of center at 400 MA 1050 VDC or 1190 VDC. PA-6	**35.00**
PA-113	1600 or 2000 each side of center at 400 MA 1370 VDC or 1720 VDC. PA-6	**57.50**
PA-114	2500 or 3000 each side of center at 500 MA 2160 VDC or 2620 VDC. UTS case	**76.00**
PA-154	3500, 4000 each side of center at 500 MA 3050 VDC or 3500 VDC. UTS case	**100.00**
PA-115	C bias plate transformer for class B 203A's, 830B's, 800's, or 210's using one or two 82 rectifiers. PA-3	**10.00**
PA-116	1250 or 1400 each side of center at 200 MA 1050 VDC or 1190 VDC. PA-5	**25.00**
PA-117	3500 or 3000 each side of center at 1 ampere. 2620 VDC or 3050 VDC. UTS case	**115.00**

NOTE: Operating the above transformers on 115 volt line the DC output voltage can be reduced to half of normal value, for reduced power operation, by switching to the 220 volt tap.

CLASS B INPUT SWINGING CHOKES*

Type	Swinging Action	Current Range	Maximum DC Oper. Voltage	Ohmic Resistance	List Price	Case
PA-101	5 to 25 henrys.	15 to 150 MA	450	115	$5.00	PA-2
PA-103	5 to 25 henrys.	20 to 200 MA	600	110	8.00	PA-3
PA-105	6 to 30 henrys	25 to 250 MA	1300	90	12.00	PA-4
PA-107	20 to 100 henrys	25 MA to 250 MA	2600	240	20.00	PA-5
PA-109	5 to 25 henrys	75 to 500 MA	1300	60	20.00	PA-5
PA-1C	5 to 25 henrys	100 to 1000 MA	4000	50	35.00	UTS

TRAP RESONANT SMOOTHING CHOKES*

Smoothing Chokes have an off center tap for hum bucking arrangements.

Type	Inductance	DC Output	Ohmic Resistance	List Price	Case
PA-100	8 henrys	150 MA	115	$5.00	PA-2
PA-102	10 henrys	200 MA	110	8.00	PA-3
PA-104	12 henrys	250 MA	90	12.00	PA-4
PA-106	35 henrys	250 MA	240	20.00	PA-5
PA-108	10 henrys	500 MA	60	20.00	PA-5
PA-1S	**10 henrys**	1000 MA	50	35.00	UTS

* Test voltage is twice maximum peak voltage plus 1000 volts.

MODULATION CHOKES

Type	Inductance	D.C. Output	Ohmic Resistance	List Price	Case
150	30 Henrys	125 MA	550	12.50	PA-3
151	30 Henrys	200 MA	425	20.00	PA-5
152	30 Henrys	400 MA	300	32.50	PA-5

UTC CONTROLLED CARRIER COMPONENTS

The **UTC Variactor** controlled carrier modulation system:

- Increases blanket DX coverage many times.
- Almost doubles Class C tube ratings and will double to quadruple Class B linear tube ratings.
- Allows power consumption saving of 50% or over.
- Reduces interference between stations tremendously.
- Increases Fidelity.

UTC bulletin 11CC gives full details on this new system of transmission.

The Essential Variactor Unit Required for Controlled Carrier Modulation Is Now Available in Six Types to Take Care of Transmitters From 25 to 800 Watts Input.

CV VARIACTORS FOR CONTROLLED CARRIER CLASS C

		List Price
CV-1	25 to 50 watts maximum input controlled class C	$ 7.50
CV-2	50 to 100 watts maximum input controlled class C	10.00
CV-3	100 to 170 watts maximum input controlled class C	15.00
CV-4	170 to 300 watts maximum input controlled class C	20.00
CV-5	300 to 500 watts maximum input controlled class C	25.00
CV-6	500 to 800 watts maximum input controlled class C	33.00

AV AUTOTRANSFORMERS FOR CV VARIACTORS—115/170 VOLTS AC

	List
AV-1 for use with CV-1	$ 5.00
AV-2 for use with CV-2	6.00
AV-3 for use with CV-3	7.00
AV-4 for use with CV-4	9.00
AV-5 for use with CV-5	12.00
AV-6 for use with CV-6	15.00