June 26, 1945. R. C. SHAW 2,379,042

MODULATOR

Filed April 28, 1942

FIG. 1

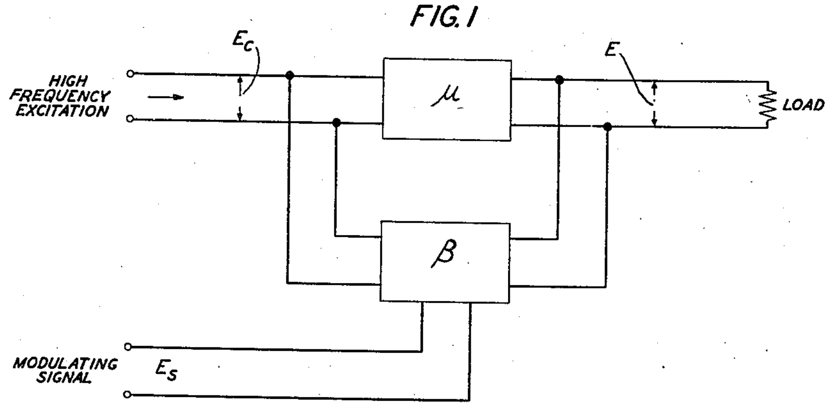
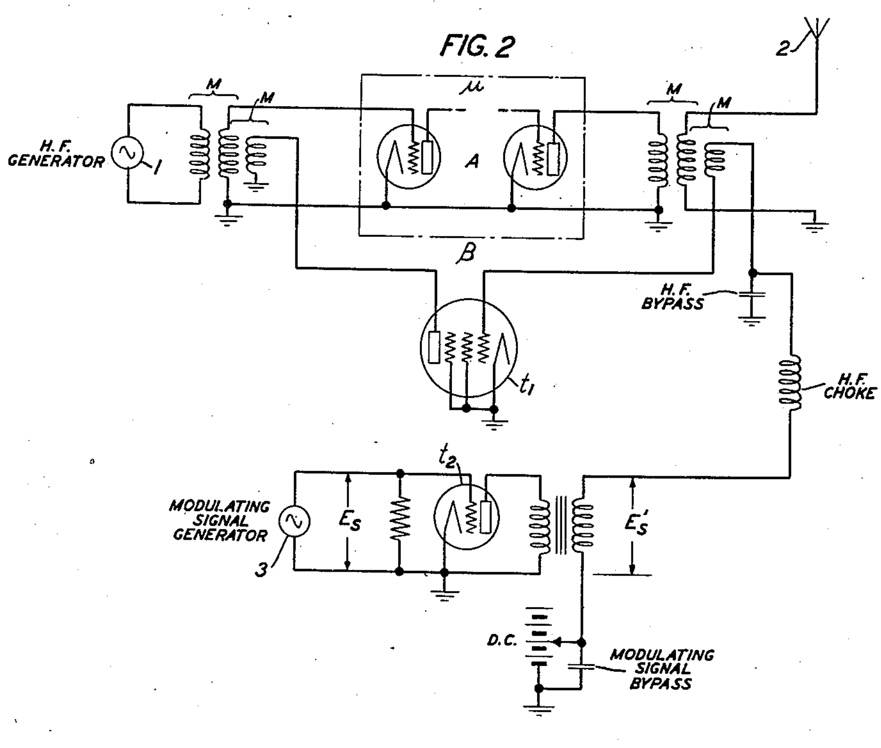


FIG. 2



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MODULATOR

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3 Claims. (Cl. 179—171.5)

This invention relates to systems of modulation involving amplifiers operating with low distortion.

One object of this invention is concerned with a system of modulation, involving feedback amplifiers and operating by variation of the feedback in accordance with modulation potentials applied within the feedback loop.

A further object of this system of modulation is to vary the effective loss in the β (beta) circuit of a low distortion negative feedback carrier amplifier in accordance with modulating potentials, applied to the grid of a variable gain vacuum tube located in the β circuit.

Referring to the figures of the drawing:

Fig. 1 is a schematic diagram intended to illustrate the basic principles of the invention; and

Fig. 2 is one practical embodiment of the novel modulator wherein a vacuum tube device is utilized to control the effective loss in the feedback loop of the negative feedback carrier amplifier.

Referring to the schematic circuit of Fig. 1 specifically, a carrier frequency amplifier utilizing stabilized negative feedback is shown, with a forwardly feeding or μ path, and a feedback or β path, in combination with means for varying the amount of negative feedback in accordance with modulating signal potentials.

The μ section of the negative feedback amplifier is conventional in design, with normal excitation from a source of wave energy to be modulated and with normal load connections. The β circuit is modified to provide an effective loss whose amount can be varied in accordance with the amplitude of a modulating voltage.

Essentially, the principle of operation of the system involves the amplification of a carrier wave in a low-distortion stabilized negative feedback amplifier and the variation of carrier feedback in accordance with a modulating potential applied within the feedback loop to produce a modulated wave in the output load.

The mathematical and theoretical relationships applying to the schematic of Fig. 1 are briefly derived from the following considerations:

Assuming that the input and output circuits of the feedback amplifier are conjugate to the β-feedback path, then the following relationships exist:

$$E=E_c\frac{\mu}{1-\mu\beta}=E_c\cdot\frac{1}{-\beta}\,\frac{(-\mu\beta)}{(1-\mu\beta)} \qquad (1)$$

where

E=output voltage

E_c=carrier input voltage

μ=complex amplification factor in the forward path

β=complex loss factor in the feedback path

Now, if $|\mu\beta|>>1$ then,

$$\left|\frac{\mu\beta}{1-\mu\beta}\right|\doteq 1$$

and it can be assumed that

$$E=\frac{E_c}{-\beta}$$

Now, if $|\beta|$ were to be varied by means of the modulating voltage, the output voltage E would be inversely proportional to these changes. Assuming the β circuit to be a pure resistance, which is varied by means of the modulating signal voltage $E_s \cos st$ then

$$\beta=(\beta_0+\beta_0\, kE_s \cos st)=(1+kE_s \cos st)\beta_0 \qquad (2)$$

where

k is a constant correlating the change in β to the modulating signal; β_0 is the loss factor for no modulation, (i. e. when k or $E_s=0$).

E_s is the peak modulating signal amplitude having the frequency

$$\frac{s}{2\pi}$$

Over one cycle of the envelope frequency, β will vary between the limits of $\beta_0\,(1\pm kE_s)$. The intermediate values will depend on the value of $\cos st$.

If the carrier wave is $E_c \cos ct$ having peak amplitude of E_c and frequency

$$\frac{c}{2\pi}$$

the output voltage will now be

$$E=\frac{E_c \cos ct}{-\beta_0(1+kE_s \cos st)}$$

which except for the inversion of $(1+kE_s \cos st)$ is the familiar expression for a carrier wave c modulated by a signal s to produce a double sideband carrier wave having a degree of modulation k.

The following table illustrates this modulation process under the conditions set forth above and where β_0 has been arbitrarily chosen as $\frac{1}{30}\ |0$, $kE_s=0.67$ and $\mu=-1,000\ |0$.

Condition	$\frac{1}{\beta_0(1+kE_s \cos st)}$	Output voltage E	Amount of feedback $\|1-\mu\beta\|$	$\left\|\frac{\mu\beta}{1-\mu\beta}\right\|$
			Decibels	
No modulation $\cos st=0$	30	$30\ E_s \cos ct$	30.44	0.972
Modulation trough $\cos st=1$.	18	$18\ E_s \cos ct$	35.05	0.982
Modulation peak $\cos st=-1$.	90	$90\ E_s \cos ct$	21.65	0.918

It may be seen that a variation in the amount of feedback from approximately 22 to 35 decibels resulted in the carrier being modulated by 67 per cent. The deviation in linearity of the output envelope from the modulating signal, assuming $|\mu\beta|>>1$ can be determined by the departure of

$$\left|\frac{\mu\beta}{1-\mu\beta}\right|$$

from 1. It is shown in the table that the deviation, for this example, amounts to only a few per cent and with the distortion correspondingly small.

Representative embodiments of modulation circuits utilizing the principle of modulating in the β loop of a carrier feedback amplifier are shown in Fig. 2. Power supply showings, and other conventional accessory and by-pass circuits, have been omitted from Fig. 2 for purposes of simplification.

Fig. 2 shows a carrier frequency feedback amplifier driven at frequency

$$\frac{c}{2\pi}$$

by the high frequency generator 1 and supplying power to a load such as an antenna 2. The amplifier A has a μ path and a β path. The μ path, which is the forwardly feeding portion of the amplifier, is in conventional arrangement. However, in the β circuit an amplifier tube t_1 is inserted suitable for amplifying at frequency

$$\frac{c}{2\pi}$$

The tube t_1 is of the variable mu type so that its gain and thus the effective loss in the β circuit can be varied by means of its grid bias. The grid bias is provided by a direct current electromotive force in series with the modulating electromotive force E_s' supplied by the amplifier t_2 operating at a frequency

$$\frac{s}{2\pi}$$

and fed from a modulating signal generator 3.

Thus, voltage variations in the modulating signal

$$\frac{s}{2\pi}$$

produce corresponding changes in loss in the feedback amplifier β circuit. The factor k of Equation 2, as it applies to the circuits of Figs. 1 and 2 depends on the tube and circuit elements as well as on the operating points selected. It may be desirable in some applications to make k a non-linear function by altering the characteristics of the amplifier t_2 by appropriate means.

Transmission through the β circuit is determined by the coupling circuits, tube t_1 and the direct current and signal frequency biasing electromotive force applied to the control grid.

What is claimed is:

1. A method of modulating a high frequency carrier wave of frequency

$$\frac{c}{2\pi}$$

with a signal wave of frequency

$$\frac{s}{2\pi}$$

said method comprising amplifying the carrier voltage between an input and an output point, negatively feeding back therebetween a portion thereof under the operating condition $|\mu\beta|>>1$ where

μ=complex amplification factor in the forward feed path

β=loss factor in feedback loop

and varying said transmission loss factor β as a function of the modulating signal voltage.

2. A modulation system comprising a source of high frequency carrier oscillations, a low distortion negative feedback amplifier for amplifying said high frequencies, and adapted to operate under the condition $|\mu\beta|>>1$ where

μ=the complex amplification factor in the forward feed path,

β=the loss factor in the negative feedback path,

a variable gain vacuum tube located in the feedback path of said amplifier, a source of modulating signal potentials, and means adapted to vary the gain of said vacuum tube in accordance with said modulating potentials.

3. A modulation system comprising a source of high frequency oscillations, a low distortion stabilized negative feedback amplifier adapted to feed forward said oscillations with positive amplification and to negatively feed back said oscillations without frequency change under the operating condition

$$E=\frac{E_c}{-\beta}$$

where

E=the output voltage of the amplifier,

E_c=the high frequency input voltage,

β=the feedback transmission loss factor,

and means for modulating said high frequency oscillations by varying said transmission loss factor β.

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