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RADIO FREQUENCY AMPLIFIER

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Fig. 1

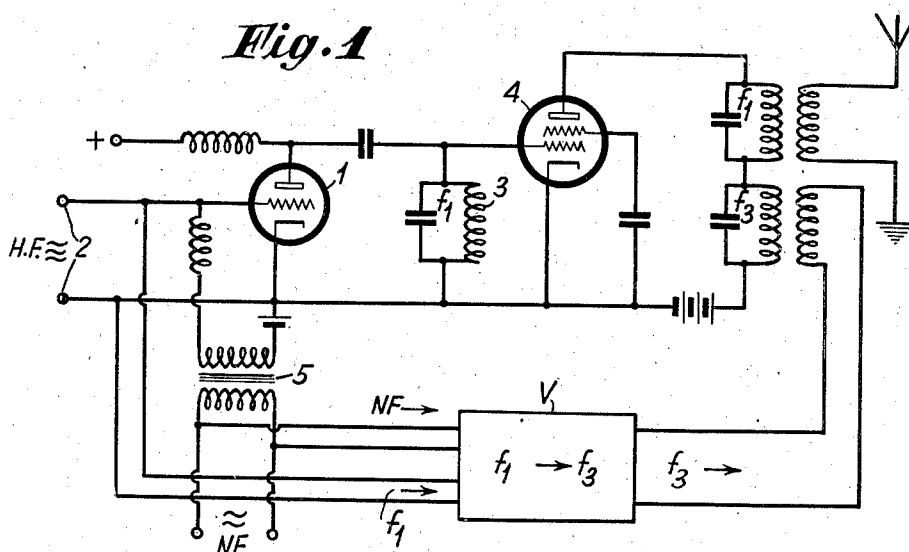
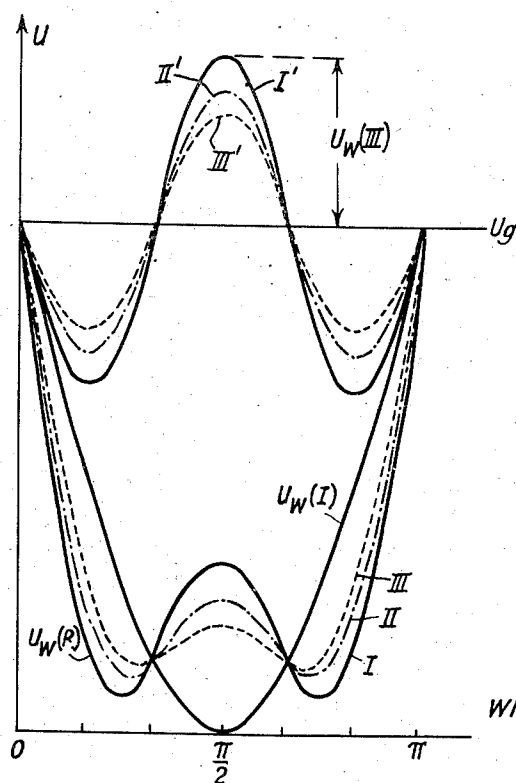


Fig. 2



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RADIO FREQUENCY AMPLIFIER

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5 Claims. (Cl. 179-171.5)

The present invention is concerned with a method adapted to improve the efficiency, that is, to raise the power output, of tubes of the class A and B carrier-wave amplifying type, of the kind employed, for instance, in input-stage-modulated transmitters as power amplifiers, for reasons of their rectilinearity.

It is an object of my invention to increase the power output in an amplifier. This is secured by the introduction of odd harmonics (third, fifth, etc.) of suitable amplitude and suitably phased so as to broaden and flatten or otherwise re-shape the fundamental waves of plate voltage.

My invention will now be explained in more detail as shown in the accompanying drawing in which

Figure 1 is a circuit diagram of a preferred embodiment; and

Fig. 2 is a diagram showing, comparatively, different wave shapes obtainable in the output circuit of my improved amplifier.

Referring to Fig. 2, U is the plate potential and I the plate current. The index g represents D. C. voltage or current, and the index w refers to alternating voltage or current. The fundamental wave and the harmonics are designated by (I), (III) etc. as raised indices, while a similar index (R) stands for resultant potential or current.

The fact that the efficiency may be improved by the use of ripple-shaped alternating plate potential as such has been known in the prior art for a long while. According to the disclosures of Rukop, Barkhausen, and Round (see the book by Zenneck-Rukop, entitled "Drahtlose Telegraphie," 1925, pp. 573, et seq.), this efficiency increase is said to have been obtained by inserting in the plate lead resonance resistances suitable for the harmonics to be used. However, this scheme presupposes that the plate current also contains these harmonics, in other words, that it is also ripple-shaped. In the case of ideal tubes (residual potential $U_R=0$), for such an arrangement the tube output power of the fundamental wave (Index I) is

$$N_R^{(I)} = \frac{1}{2} \left(\frac{4}{\pi} \frac{I_g}{2} \right) \left(\frac{4}{\pi} U_g \right)$$

the input power

$$N_g = \frac{I_g}{2} U_g$$

and thus the theoretically maximum efficiency

$$\eta = \frac{N_R}{N_g} = \frac{8}{\pi^2} = 81\%$$

Now, contradistinct to this scheme I provide

the means for maintaining a somewhat distorted sinusoidal wave shape of the output energy. But waves of this kind contain substantially no component of the higher odd harmonics, a fact demonstrated not only by the Fourier analysis, but which is demonstrable in a purely graphic form by assuming a full sine-wave plot to result from, or to be the sum total of the Fourier components of two lines representing half waves. Members of odd order in this case would become added and would not vanish in line with what is required. Hence, the requisite distortion of the plate alternating potential can not be obtained by resonance resistance for the third or for higher odd harmonics as is true of the known circuit scheme. In fact, according to the invention, the required voltage components are separately produced and induced into the plate lead. For instance, in the case of the third harmonic this is illustrated in Fig. 1. Inasmuch as the plate current contains no components of these frequencies, the harmonic voltage sources are neither fed with energy nor is energy derived therefrom. Hence, the energy amount required for the production of these potentials is so small as to be negligible.

Referring to Fig. 1, 1 denotes the input amplifier tube, the grid circuit of which is fed with the RF energy at the terminals 2. The plate circuit of this tube is tuned to the fundamental wave f and is associated with the control grid of the transmitter tube 4. The modulation frequency NF is fed to the input stage 1 by way of the transformer 5. Also associated with terminal 2 is a frequency multiplier stage V in which, for instance, the third harmonic $f/3$ of the fundamental wave is generated. This harmonic may also be modulated by AF. The third harmonic is induced in the plate lead of tube 4.

For practical purposes, it suffices to introduce only the third harmonic, though also higher odd harmonics could be added. Fig. 2 shows the form of the resultant voltage curve $U_w^{(R)}$ in this case, that is, first (curve I) for the voltage of the third harmonic

$$U_w^{(III)} = \frac{1}{3} U_w^{(I)}$$

an intermediate value (curve II) and for

$$U_w^{(III)} = \frac{\pi}{4} U_w^{(I)}$$

a value which at the time of maximum grid potential, and thus also current output, results

in the same residual potential as the purely ripple-shaped wave. The output power is

$$N_R = \frac{U_w^{(R)}}{\sqrt{2}} \cdot \frac{I_w^{(R)}}{2\sqrt{2}}$$

the input power

$$N_a = U_s \cdot \frac{1}{\pi} I_w^{(R)}$$

and thus the efficiency of the tube

$$\eta_R = \frac{N_R}{N_a} = \frac{\pi}{4} \frac{U_w^{(R)}}{U_s}$$

U_s with the addition of third harmonics equal in amount to curve III may be made just $4/\kappa$ times greater than without this step, with the additional result that the tube power which is delivered is made to rise to a like extent. The tube efficiency, in the presence of the residual potential U_R required for a given working stage assumes this simple form

$$(\eta_R)_{III} = \frac{U_s - U_R}{U_s} = 1 - \frac{U_R}{U_s}$$

In the case of an ideal tube free from residual voltage, therefore, the theoretically highest efficiency of 100 percent would be obtained (in contrast to 81 percent in the case above mentioned).

For a working voltage of 12 kv. and a residual voltage of around 1200 v. (which corresponds to the conditions of the 200 kw. tube model RS 301) a tube efficiency of approximately 90 percent is possible, as compared with 70.9 percent without the addition of the third harmonic. Inasmuch as the alternating plate current and the intake practically decline in direct proportion as the modulation is reduced, it follows that when assuming a loss of 5 percent in the intermediate circuits, the carrier efficiency becomes $\eta_{Tr} = 42.8$ percent and the upper-limit efficiency $\eta_{Ob} = 85.4$ percent.

I claim:

1. In a radio frequency circuit arrangement, a high-frequency amplifier, means for feeding a carrier wave to said amplifier, frequency mul-

tiplier means for impressing on the output circuit of said amplifier an odd harmonic component of said carrier wave, and means for so controlling the amplitude and phase of said odd harmonic component as to broaden and flatten the fundamental wave peaks derived from said amplifier.

2. A circuit arrangement comprising a high frequency amplifier having at least one stage the output circuit of which includes resonant elements tuned to a fundamental frequency and to an odd harmonic frequency, a frequency multiplier having an output circuit coupled to the inductance of said harmonically tuned resonant element, and energy diversion means connected to the source of input energy for said amplifier and arranged to feed input energy to said frequency multiplier.

3. A circuit arrangement according to claim 2 wherein said harmonically tuned resonant element is tuned to the third harmonic of said fundamental frequency.

4. A circuit arrangement according to claim 2 wherein means are provided for combining the output energies from said amplifier and said frequency multiplier in suitable amplitude and phase relations to produce broadened and flattened fundamental wave peaks.

5. A circuit arrangement comprising a high frequency amplifier having at least one stage the output circuit of which includes inductive and capacitive elements having resonance to a fundamental frequency and to an odd harmonic of that frequency, a frequency multiplier having an output circuit coupled to that inductive element which resonates at said harmonic frequency, carrier wave and modulation frequency sources both coupled to the input circuits of said amplifier and of said frequency multiplier, and a utilization circuit coupled to that inductive element which resonates at said fundamental frequency, and arranged to receive energy components both from said amplifier and from said frequency multiplier.

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