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CODER FOR CODE MODULATION TRANSMISSION

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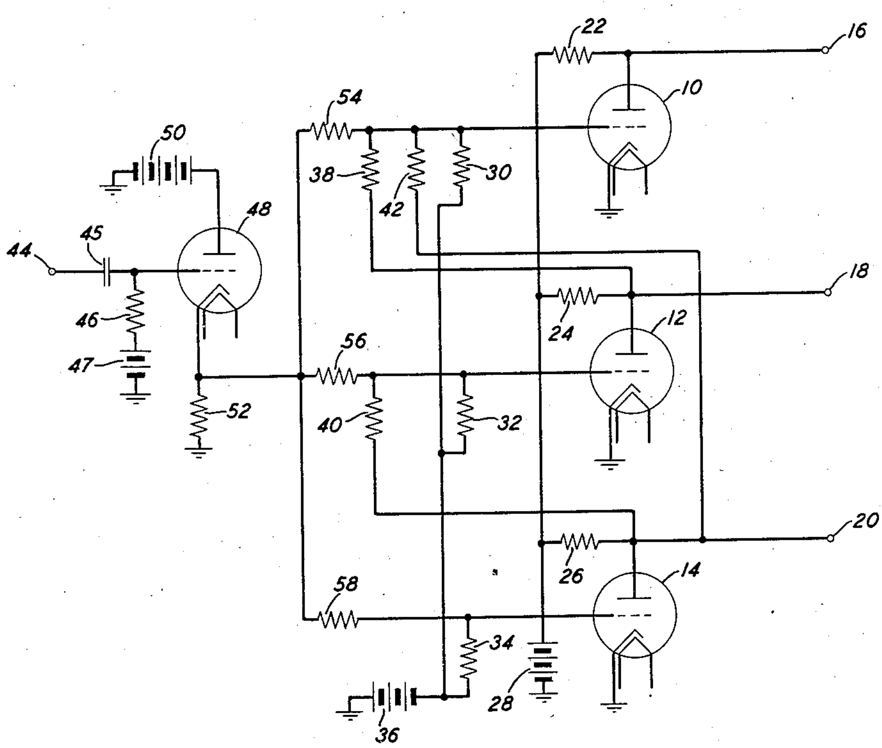

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CODER FOR CODE MODULATION TRANSMISSION

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7 Claims. (Cl. 179—1.5)

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This invention relates to coders for use in code modulation transmission systems of the type disclosed in a copending application for a United States patent, Serial No. 677,667 of J. C. Schelling filed June 19, 1946, and more particularly to improved apparatus for expressing the instantaneous amplitude of a complex wave to be transmitted as a binary code group of voltages suitable for transmission to a remote point.

In code modulation transmission systems the instantaneous amplitude of the complex wave to be transmitted is converted into a code group of signaling voltages representative of that amplitude. In such systems the code may be based upon the binary counting system in accordance with which each of the plurality of signaling voltages may represent one of the denominational orders of the binary number and thus represent a fixed portion of the total possible amplitude of the complex wave expressed as a binary number. Each of the signaling voltages has two values and in one value represents the presence of a fixed portion of the total possible amplitude while in the other value it represents the absence of that portion. In general, the fixed portions of the total are related in amplitude as powers of two. Since each of the signaling voltages may have either of two values, the total number of permutations which can be obtained between n signaling voltages is 2^n. Thus a three element code permits unique expression of 2^3 or eight discrete amplitudes and similarly a five element code permits expression of 2^5 or thirty-two different amplitudes.

One type of apparatus for generating such binary code groups of signaling voltages involves a coder for providing separate signaling voltages individual to each of the denominational orders of the binary number code and suitable for transmission over separate channels to a remote station. Since such coders must provide separate signaling voltages, each of which is referred to ground potential to facilitate individual transmission in separate channels they have necessarily been relatively complex employing numerous vacuum tubes and associated circuits. Such complex arrangements increase the space, power and maintenance requirements of the equipment and limit the usefulness of this type of equipment in many applications.

It is an object of the invention to provide means for continuously expressing the instantaneous amplitude of a complex wave in terms of a plurality of bi-valued signals each representing a fixed portion of the total possible amplitude of the complex wave.

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It is a further object of the present invention to provide a coder of the type referred to above which will be small, light in weight, have low power requirements and avoid the relatively complex circuit arrangements common to previous coders of this general type.

The invention relates in one aspect to a coder comprising a plurality of relays or vacuum tubes each controlling an output signal representative of a different fixed portion of the total possible amplitude of the complex wave to be transmitted, means for applying the complex wave to all of the relays in parallel and means for applying individually to each of the relays separate voltages derived from all of the relays which control signals representing larger portions of the total possible amplitude, such voltages being respectively proportional to the output signals of the last-mentioned relays.

The coder of the invention employs one relay or vacuum tube for each denominational order of the binary code. Thus, if an n-element code is employed, the coder of the present invention comprises n vacuum tubes or relays, one for each element of the code, plus a single input tube common to all of the coding elements. For purposes of illustration a coder embodying the present invention is arranged to express the instantaneous amplitude of the complex wave by a three-element binary code giving an amplitude range of 2^3 or eight units. Since the complex wave ordinarily has both positive and negative values, it is convenient to apply a fixed bias to the coder such that the base line or zero axis of the complex wave falls at the approximate center of the operating range of the coder. Thus a coder employing three-element binary code as above can accommodate a peak-to-peak signal of eight units or positive or negative signals approximately four units in amplitude.

The above and other features of the invention will be described in the following detailed specification and pointed out in the accompanying claims.

In the drawing, the single figure is a schematic diagram of a coding circuit in accordance with the invention.

As shown in the drawing, the coder for expressing the instantaneous amplitude of a complex wave in three-element binary code comprises selector tubes or relays 10, 12 and 14 controlling separate output signals which appear at terminals 16, 18 and 20, respectively. In accordance with the binary coding system considered above, each of these selectors controls a voltage representative of a fixed portion of the total possible amplitude of a complex wave to be transmitted, these portions being related in amplitude as powers of two. Thus selector 10 controls an output representing one unit of amplitude of the complex wave while selectors 12 and 14 control outputs representing respectively two and four units. By suitable control means, the operation of these selectors may be switched so that the combination of their output signals forms any one of eight different permutations. Conveniently, the unit of measurement employed may be one volt and in this case eight different amplitudes from 0 to 7 volts inclusive may be expressed uniquely.

Conveniently, each of selectors 10, 12 and 14 may comprise a triode type vacuum tube although other types of vacuum tube circuits having two different operating conditions or conditions of stability may be employed with equally advantageous results. The plates of selector tubes 10, 12 and 14 are connected through load resistors 22, 24 and 26, respectively, to the positive terminal of battery 28, the negative terminal of which is connected to ground. In addition the plates of these selectors are respectively connected to output terminals 16, 18 and 20. The cathodes of the selector tubes are connected directly to ground while their grids are connected respectively through resistors 30, 32 and 34 to the negative terminal of bias battery 36 the positive terminal of which is connected to ground.

In addition to the above connections the plate of selector tube 12 is connected through resistor 38 to the grid of selector tube 10 while the plate of selector tube 14 is connected through resistor 40 to the grid of selector tube 12 and through resistor 42 to the grid of selector tube 10.

The complex wave to be represented in binary code form for transmission is applied at terminal 44 and thence through a blocking capacitor 45 to the grid of a cathode follower 48 the grid circuit of which includes resistor 46 in series with bias battery 47. This cathode follower may conveniently comprise a triode type vacuum tube the plate of which is connected to the positive terminal of a battery 50 the negative terminal of which is grounded, the cathode of the tube being connected through load resistor 52 to ground. The voltage appearing across load resistor 52 is an accurate reproduction of the voltage applied at terminal 44 and is applied through resistors 54, 56 and 58, respectively in parallel to the control grids of selectors 10, 12 and 14.

In considering the operation of the coder of the invention, let it be assumed that the bias voltage from battery 47 is positive and substantially equal to one-half the largest possible peak-to-peak amplitude of the complex wave to be transmitted. In other words, the bias voltage is such that in the absence of applied complex wave (or when the complex wave is of zero amplitude) the voltage at the output of cathode follower 48 will fall at the approximate center of the operating range of the coder. Then all of the voltages appearing across cathode resistor 52 and applied through series resistors 54, 56 and 58 to the selectors will be of positive polarity and will tend to oppose the negative bias applied to these selectors from battery 36.

In order to simplify the following description of operation of the coder it is convenient to measure the amplitudes of the voltages appearing across cathode resistor 52 of cathode follower 48 in respect to ground. It will be remembered that the complex wave is superimposed on a positive bias equal to substantially one-half its maximum possible peak-to-peak amplitude whereby the voltage across cathode resistor 52 is at approximately the center of the operating range of the coder for a complex wave of zero amplitude. Thus, measuring from ground, the voltage across resistor 52 is of zero amplitude when the complex wave has its maximum possible negative value, has an amplitude of between three and four units (of the exemplary coder's total range of eight units) when the complex wave has zero amplitude, and has an amplitude of seven units when the complex wave reaches its maximum possible positive amplitude. In the following description all input voltages to the coder will be those appearing across resistor 52, measured in respect to ground and comprising the summation of the complex wave applied at terminal 44 with the positive bias contribution from battery 47.

The negative bias from battery 36 is made effective in the absence of voltages across cathode resistor 52 of cathode follower 48 to cut off the flow of current in the selector tubes. Accordingly, the plate voltages of these tubes rise and relatively high voltages appear at output terminals 16, 18 and 20.

Because of the interconnections between selectors 12 and 10, between selectors 14 and 12 and between selectors 14 and 10, positive voltages are applied to the grid of selector 10 whenever selectors 12 or 14 are cut off and to the grid of selector 12 whenever selector 14 is cut off. Furthermore, whenever selectors 12 or 14 become saturated due to the application of a sufficiently high positive voltage to their grids, the positive voltage contributions therefrom to the grids of the other selectors are removed.

In the grid circuit of selector 12, resistors 40, 56 and 32 are so proportioned that at the grid the positive voltage contribution from coder 14 when cut off bears the same relation to the portion of the total amplitude represented by coder 14 (in this example, 4 units) as the input voltage contribution at the grid applied through resistor 56 bears to the amplitude of the complex wave applied at input terminal 44. In other words, if the voltage contribution at the grid of selector 12 corresponding to an input signal of amplitude A has an amplitude of a arbitrary units, then the positive contribution from selector 14 when cut off has an amplitude of 4 in the same arbitrary units.

Similar relationships obtain between the voltages applied to selector 10 from input terminal 44 and from the plates of selectors 12 and 14. Thus when an input signal of amplitude A results in a signal at the grid of selector 10 a arbitrary units in amplitude, the contribution from selector 14 when cut off is of amplitude 4 in the same arbitrary units and that from selector 12 is of amplitude 2 in the same arbitrary units. It should be noted that the arbitrary units employed in measuring the relative amplitudes of the voltages applied to the several selectors needs not be the same for each selector so long as the relationships defined above are preserved in a consistent system of units at the input of each selector.

It will be recalled that in the absence of other applied voltages, the negative bias from battery 36 is effective to cut off each of the selector tubes. This bias voltage is also sufficient to maintain selector 12 cut off despite the positive contribution from cut-off selector 14 and to maintain selector 10 cut off despite the positive contributions from cut-off selectors 12 and 14. Since two such positive contributions are applied to selector 10 a lower input signal amplitude is required to saturate this selector than is required to saturate selector 12 in which the input signal is aided by only one positive contribution.

More specifically, in the exemplary system considered herein, the negative bias voltage and the proportions of the resistances in the grid networks of the selectors are so chosen that, when all selectors are cut off an input signal of at least one volt is required to saturate selector 10. Similarly, when selector 14 is cut off an input of 2 volts is required to saturate selector 12 and an input of 4 volts is required to saturate selector 14. If the positive contributions from selector 14 to selector 12 and from selectors 12 and 14 to selector 10 are removed, the input voltage must be increased correspondingly to cause saturation of the selector involved.

Turning now to the detailed operation of the circuit, let it first be assumed that the input signal across resistor 52 is zero. Then each of selectors 10, 12 and 14 is cut off and high voltages which may denote the zeros of a binary number, appear at output terminals 16, 18 and 20. The binary code group obtained by setting down the values (one or zero) of the outputs at these terminals is thus 000. Hereinafter such binary code groups will be written by listing the signals appearing at terminals 20, 18 and 16 in that order. This corresponds to listing the code element representing the highest denominational order of the binary number first reading from left to right in the usual manner.

If, for example, the instantaneous amplitude of the complex wave to be transmitted is such that one volt appears across resistor 52, one volt is applied to each of resistors 54, 56 and 58. As to selector 10, the positive voltage corresponding to the applied 1-volt signal plus the positive contributions from cut-off selectors 12 and 14 is sufficient to overcome the negative bias from battery 36 and to cause the flow of saturation current through selector 10. The voltage applied to selector 12 in response to the 1-volt signal is insufficient, even with the positive contribution from selector 14, to overcome the negative bias and this selector remains cut off. Similarly, the voltage applied to selector 14 in response to a 1-volt signal is not sufficient to overcome the negative bias on this selector. Accordingly, with the application of a signal of one volt, selectors 12 and 14 remain cut off and selector 10 becomes saturated. The voltage at output terminal 16 drops to a relatively low value and the binary code group obtained by listing the signals on the output terminals becomes 001.

Let it now be assumed that the complex wave amplitude is such that an input signal of two volts appears across load resistor 52 of cathode follower 48. In the absence of other considerations, this voltage would be sufficient to maintain selector 10 at saturation. It would also cause the application of a positive voltage of sufficient amplitude in addition to the positive contribution from selector 14 to cause the flow of saturation current in selector 12. Resistors 58 and 34 associated with selector 14 are so proportioned that an applied voltage of two volts is insufficient to overcome the negative bias applied to this selector. It will be noted, however, that when selector 12 becomes saturated due to the application of two volts, its plate potential is lowered and the positive potential applied to the control grid of selector 10 from this tube is reduced. Accordingly, in the absence of this positive contribution, which is proportional to two volts as applied to selector 10, the negative bias from battery 36 is again effective to cut off selector 10. Thus, for an input of two volts selectors 10 and 14 are cut off while selector 12 is saturated so that the binary code group obtained at output terminals 20, 18 and 16 is 010 corresponding to an amplitude of two.

If a signal of three volts is now applied to the selectors the following action occurs. Because of the relative proportions of resistors 58 and 34, selector 14 remains cut off, the applied voltage being insufficient to overcome the negative bias from battery 36. Selector 12 becomes saturated since an input signal of only two volts is required to saturate this selector so long as selector 14 remains cut off and the positive contribution therefrom to selector 12 is maintained. On the other hand, the input of three volts produces a sufficiently large positive voltage at the grid of selector 10 to overcome the negative bias from battery 36 despite the absence of the positive contribution (which is proportional to two volts) from selector 12. Accordingly, selectors 10 and 12 are saturated and the binary code group obtained on the output terminals is 011 corresponding to an amplitude of 3.

Further, if the input voltage across resistor 52 rises to four volts selector 14 is saturated. When this selector becomes saturated, however, its plate voltage drops and the positive contributions from this selector through resistor 40 to the grid of selector 12 and through resistor 42 to the grid of selector 10 are removed. In the case of selector 12 the removal of the positive contribution from selector 14 is effective to balance the 4-volt input signal for this selector and to permit the negative bias from battery 36 to cut off the tube. When this occurs the plate voltage of selector 12 rises and a positive contribution is again applied from selector 12 through resistor 38 to the grid of selector 10. It will be recalled, however, that an input signal of one volt is required to saturate selector 10 even when positive contributions from both selectors 12 and 14 (proportional to two plus four or six volts as applied to selector 10) are applied to augment the signal.

It is thus apparent that the sum of the positive voltages applied to selector 10 must at least be proportional to seven volts to saturate this selector. Here the sum of the positive voltages is proportional to six volts, four from the input and two from selector 12, so that selector 10 is cut off and the code group appearing at the output terminals becomes 100.

In a similar way the application of input signals greater than four volts causes appropriate changes in the conditions of selectors 10, 12 and 14. For example, upon the application of five volts selector 14 remains saturated. This increased signal voltage, however, is sufficient to make the sum of the positive voltages applied to selector 10 proportional to seven volts, five from the input and two from selector 12, and this tube is saturated. On the other hand, the increase of the applied voltage is not sufficient to saturate selector 12 which remains cut off and the output code group is 101. The operation of the circuit in response to inputs of six and seven volts may be analyzed in an entirely analogous manner.

It will be understood that a wider range of amplitudes may be expressed in binary code group form by increasing the number of selectors. In each case connections must be made between each of the added selectors and the grid circuits of all selectors representing smaller portions of the total possible amplitude of the complex wave to be transmitted. Such connections must be so made that the contribution from each selector to each selector controlling a signal representative of a smaller portion of the total possible amplitude bears the same relation (in the selector to which it is applied) to the portion of the total amplitude represented by the originating selector as the signal voltage applied to the selector receiving the contribution of does to the input signal.

The coding circuit of the invention may be used in the transmitters of various types of code modulation transmission systems. For example, the separate voltages at terminals **10**, **12** and **14** of the illustrative embodiment may be individually and simultaneously transmitted or each output terminal may be sampled and the voltages thereon transmitted in sequence.

What is claimed is:

1. In a communication system, a coder for generating representations of the instantaneous amplitude of a wave to be transmitted according to a code of a plurality of code elements each representative of a different fixed portion of the total possible amplitude of said wave, said coder comprising a plurality of relays each controlling an output signal corresponding to one of said code elements, means for applying said wave to all of said relays, means for deriving from the outputs of all of said relays except that representing the largest portion of the signal amplitude voltages proportional to the amplitude portions which the relays respectively represent, and means for applying the voltage derived from each relay to each other relay controlling a larger derived voltage.

2. In a communication system, a coder for generating representations of the instantaneous amplitude of a wave to be transmitted according to a code of a plurality of code elements each representative of a different fixed portion of the total possible amplitude of said wave, said coder comprising a plurality of relays each continuously controlling an output signal corresponding to one of said code elements, means for continuously applying said wave to all of said relays, means for deriving from the outputs of all of said relays except that representing the largest portion of the signal amplitude voltages proportional to the amplitude portions which the relays respectively represent, and means for applying the voltage derived from each relay to each other relay controlling a larger derived voltage.

3. In a communication system, a coder for generating representations of the instantaneous amplitude of a wave to be transmitted according to a code of a plurality of code elements each representative of a different fixed portion of the total possible amplitude of said wave, said coder comprising a plurality of electron tubes each controlling an output signal corresponding to one of said code elements, means for applying said wave to all of said electron tubes, means for deriving from the outputs of all of said electron tubes except that representing the largest portion of the signal amplitude voltages proportional to the amplitude portions which the electron tubes respectively represent and means for applying the voltages derived from each electron tube to each other electron tube controlling a larger derived voltage.

4. In a communication system, a coder for generating representations of the instantaneous amplitude of a wave to be transmitted according to a code of a plurality of code elements each representative of a different fixed portion of the total possible amplitude of said wave, said coder comprising a plurality of electron tubes each controlling an output signal corresponding to one of said code elements, means for applying said wave to all of said electron tubes in parallel, means for deriving from the outputs of all of said electron tubes except that representing the largest portion of the signal amplitude voltages proportional to the amplitude portions which the electron tubes respectively represent, and means for applying the voltage derived from each electron tube in parallel to each other electron tube controlling a larger derived voltage.

5. In a communication system for transmitting a message wave, apparatus for generating code representations of the instantaneous amplitude of the message wave to be transmitted comprising a plurality of electron tubes each controlling an output signal representative of a different fixed portion of the total possible amplitude of said message wave, means for applying to each of said electron tubes voltages proportional to the instantaneous amplitude of the message wave, and means for applying individually to each of said electron tubes separate voltages from all electron tubes controlling signals representing larger portions of said total amplitude, said voltages as applied being proportional to the parts of the total amplitude represented by the electron tubes from which they are respectively derived in the same units as those in which the voltage proportional to the complex wave is measured.

6. In a communication system for transmitting a message wave, a coder for generating code representations of the instantaneous amplitude of the message wave, said coder comprising a plurality of selectors each controlling an output signal representative of a different fixed portion of the total possible amplitude of said message wave, means for applying a fixed bias voltage to each of said selectors, means for applying a voltage proportional to the instantaneous amplitude of the message wave in parallel to each of said selectors and in opposition to said bias voltages, and means for applying to each selector except that controlling the output signal representing the largest portion of the total possible amplitude additional control voltages, these voltages in each case also opposing said bias voltages and being respectively proportional to the amplitudes represented by the output signals of selectors controlling signals representative of larger portions of said total amplitude.

7. In a communication system for transmitting an intelligence wave, a coder for generating code representations of the instantaneous amplitude of an intelligence wave to be transmitted, said coder comprising a plurality of electron tubes each controlling an output signal representative of a different fixed portion of the total possible amplitude of said intelligence wave, means for applying a fixed bias voltage to each of said electron tubes, means for applying to each of said electron tubes and in opposition to said bias voltages voltages proportional to the instantaneous amplitude of said intelligence wave, and means for applying individually to each of said electron tubes separate additional voltages from all electron tubes controlling signals representative of larger portions of said

total amplitude, these voltages also opposing said bias voltages and, as applied to each electron tube, being proportional to the parts of the total amplitude represented by the electron tubes from which they are derived in the same units as employed in measuring the instantaneous amplitude of the intelligence wave applied to the respective tubes.

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