340-870.14 SR SEARCH ROOM
OR 2,845,613

July 29, 1958 M. G. PAWLEY 2,845,613
PHASE-SAMPLING TELEMETER
Filed Nov. 16, 1953 4 Sheets-Sheet 1

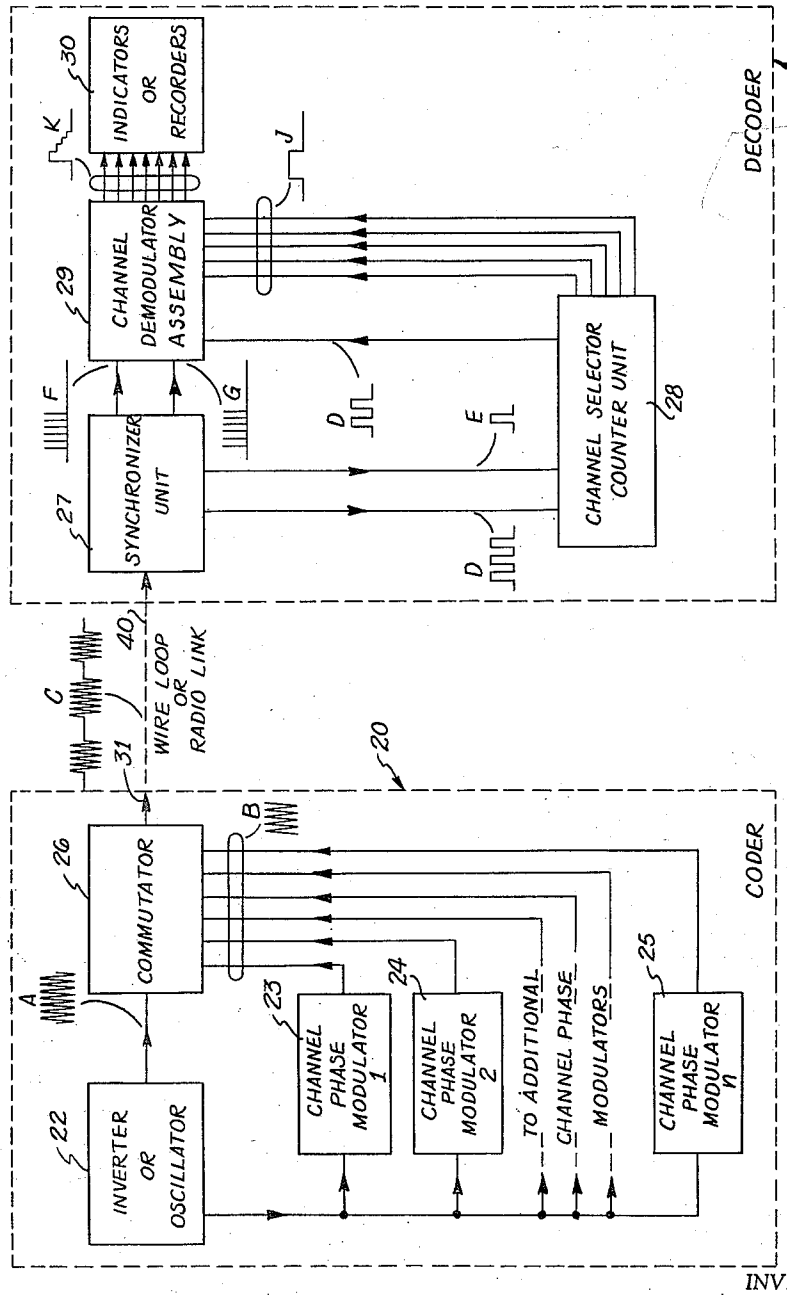


Fig. 1

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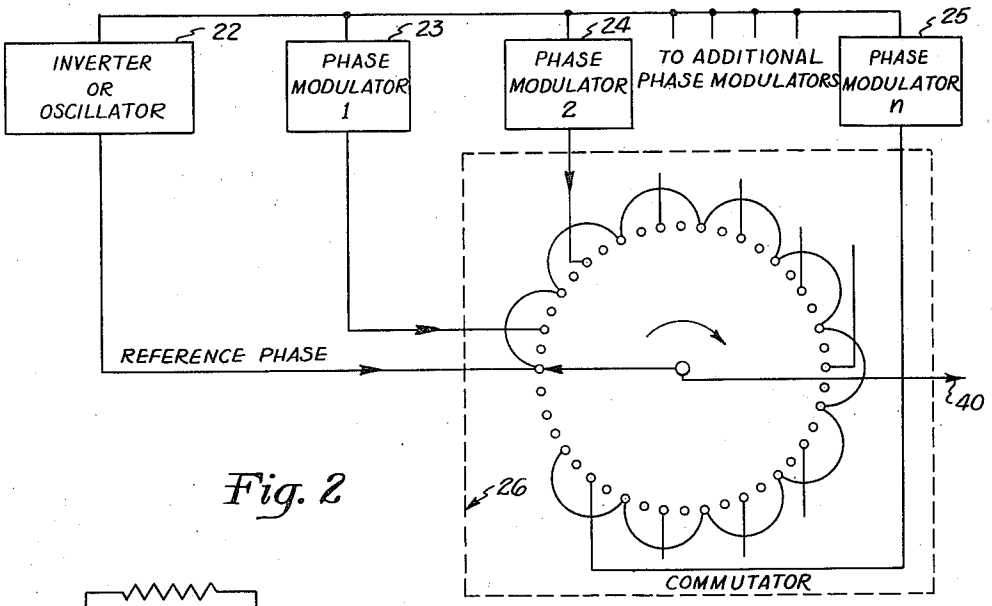


Fig. 2

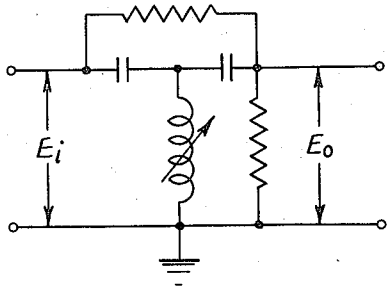


Fig. 3-A

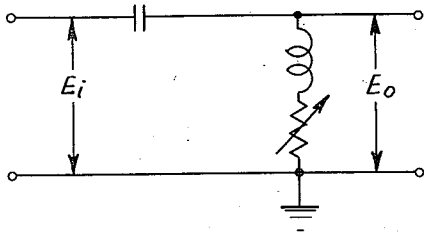


Fig. 3-B

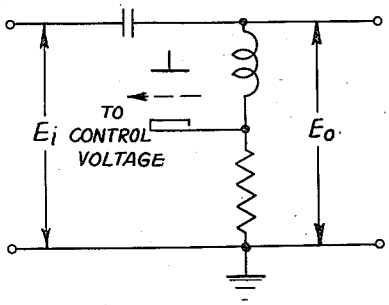


Fig. 3-C

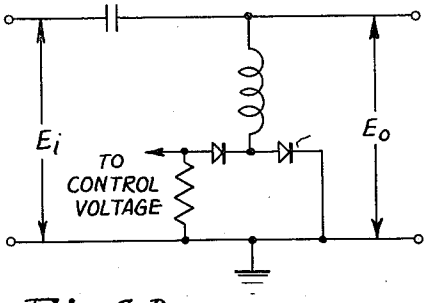


Fig. 3-D

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PHASE-SAMPLING TELEMETER

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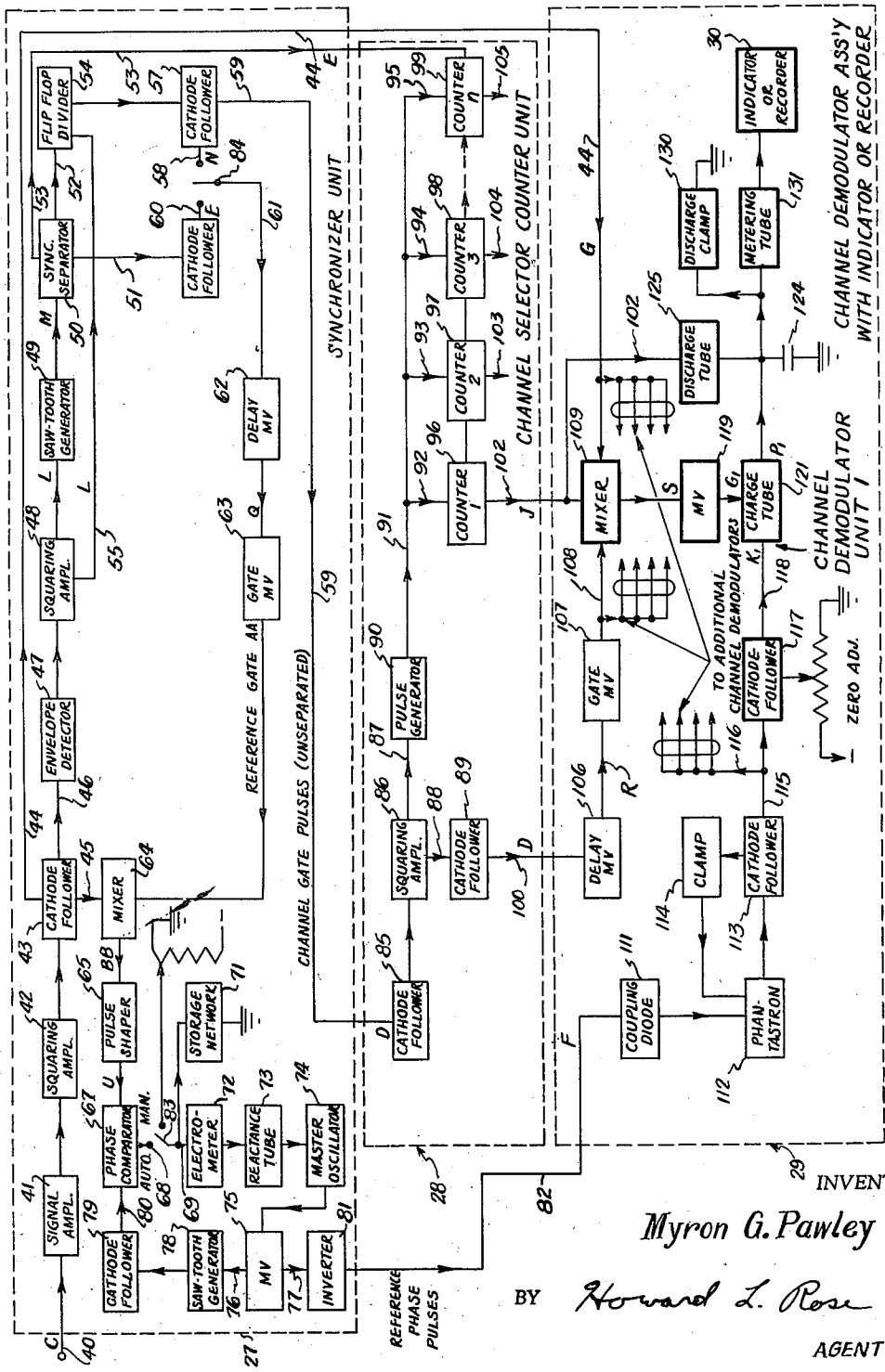


Fig. 4

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PHASE-SAMPLING TELEMETER

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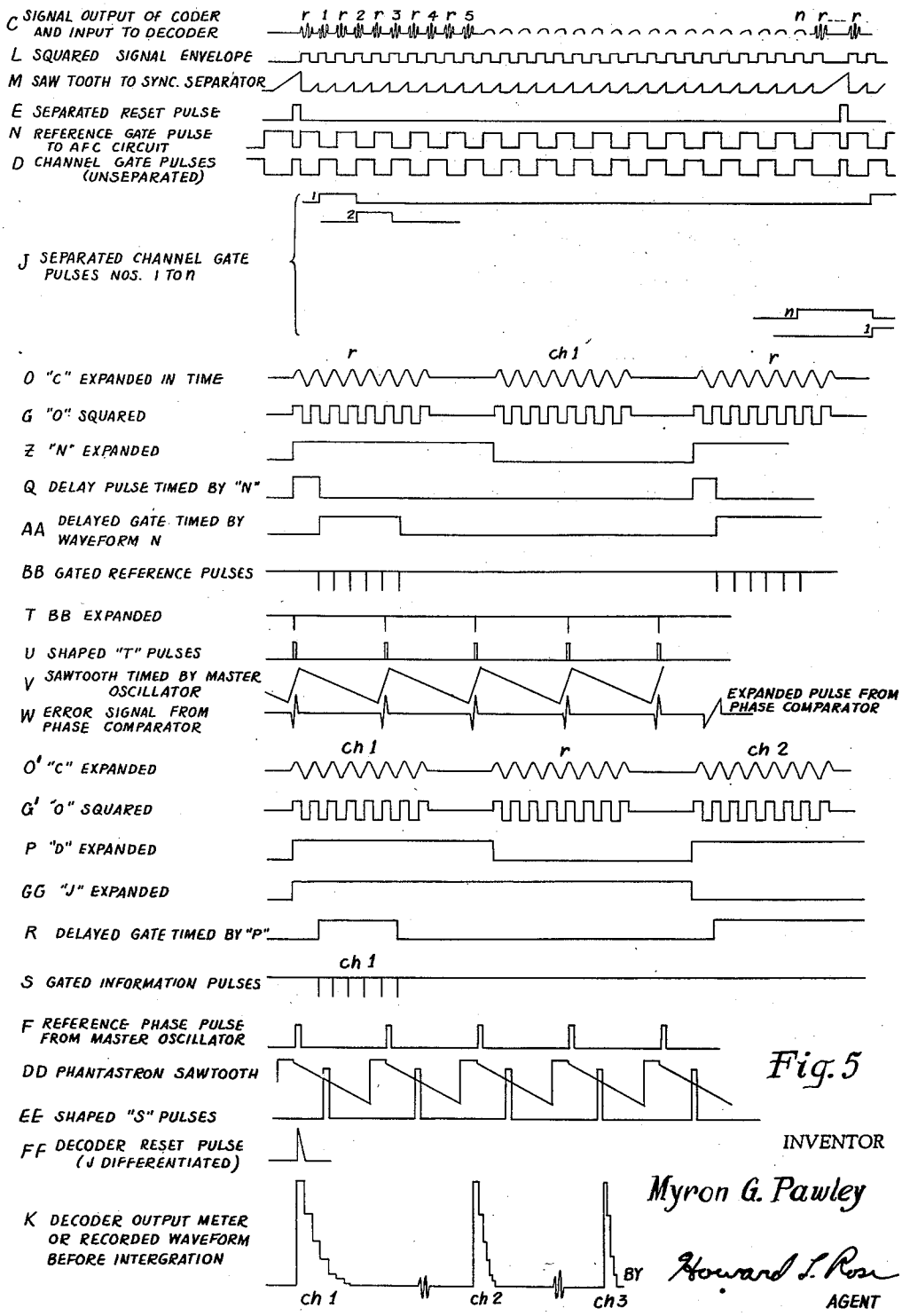


Fig. 5

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2,845,613

PHASE-SAMPLING TELEMETER

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Application November 16, 1953, Serial No. 392,528

8 Claims. (Cl. 340—183)

The present invention relates generally to telemetering systems, and more specifically to a phase-sampling telemetering system wherein a plurality of sensing devices modulate or shift the phase of a sinusoidal voltage to produce channel samples which, after sequential transmission to a distant location, are demodulated and the phase displacements of said samples are evaluated and registered on suitable indicating meters or recording devices.

In many telemetering applications it is desirable to have a compact multichannel telemeter transmitter unit of the utmost simplicity, the complexity of the decoder being relatively unimportant. An instance of such a situation would be when the coder is located in an aircraft and the decoder is located at a large ground installation. The coder should be lightweight and compact, of simple construction, both mechanically and electrically. In such cases these desirable features in the coder are obtained at the expense of complexity of the channel decoding circuitry of the decoder. However, since the decoder will be located at a ground installation this complexity can be tolerated.

Another feature which it is desirable for a telemetering system to have is a narrow bandwidth of necessary frequencies. With a narrow bandwidth the noise level may be maintained at a low value.

It is the primary object of the present invention to provide a telemetering system having a very simple coder unit.

Another object of the present invention is to provide a phase-modulation telemetering system which requires a very narrow bandwidth of freqeuncies.

It is another object of the present invention to provide means for maintaining the coder and decoder units in synchronism.

It is an object of the present invention to provide a telemetering system which utilizes only a single frequency that is slowly phase modulated.

Still another object of the present invention is to provide a coder unit requiring only one electron tube.

Another object of the present invention is to provide a telemetering system in which continuously rotational information may be supplied simultaneously in a number of channels.

The instant telemetering system comprises three parts: first, a coder consisting of either an inverter or a highly stable vacuum-tube oscillator that supplies a voltage which is used as a reference and which is also applied to a plurality of quantities to be telemetered; second, a wire loop or radio link that transmits the reference and phase-shifted voltages in sequence; and third, a suitable decoder with indicating meters or recording devices that register the decoded magnitudes of the phase-shifted voltages. Phase shifting of a sinusoidal voltage to indicate the magnitude of a quantity to be telemetered is readily obtained and may be achieved with very little equipment.

The coder produces a repeating group or frame of "bursts" of a sine wave voltage, alternate "bursts," starting with the first, consisting of a number of cycles of a reference voltage and the alternate bursts starting with the second consisting of the same frequency shifted in phase in accordance with the information to be telemetered in the various channels.

The switching or phase-sampling is accomplished by means of a motor-driven mechanical commutator. In common with other commutated telemetering schemes the decoding equipment at the receiving station is relatively complex because of the sequential nature of the commutated channel signals.

At the receiving station it is necessary to decode the several channel phase samples in order to interpret the information telemetered in these channels.

Since the reference phase sample transmitted at the start of each frame does not occur simultaneously with any of the channel phase samples, it becomes necessary to include some sort of memory circuit so that when any particular channel sample arrives there will be a reference voltage available to compare it with. A phase discriminator then provides the decoding means for indicating the magnitude and sense of the phase shift corresponding to the information being telemetered in the channel under consideration.

The memory circuit required for proper decoding action is provided in the synchronizer unit by a local reference voltage generator whose frequency is corrected each time a reference voltage sample arrives at the phase discriminator. Therefore the local reference generator voltage is maintained essentially in synchronism with the reference voltage at the transmitter.

The time gaps between successive channel phase samples and the longer time gap just prior to the reference phase sample permit frame and channel sync pulse generators in the synchronizer unit to develop suitable pulses for the energization of gates for separating the reference phase voltage and the channel phase samples. The separation of the channels is effected by utilizing a ring counter chain in the channel selector counter unit where the individual channel sync pulses are "stepped along" the ring. There is a terminal on the counter chain for each separated channel sync pulse. The selected channel phase sample and the locally regenerated reference voltage are passed to a phase discriminator in the channel demodulator unit whose output is a measure of the information being telemetered in that channel. Suitable telemetering and recording elements provide for monitoring or for storage of channel information.

Other uses and advantages of the invention will become apparent upon reference to the specification and drawings.

Figure 1 is a basic block diagram of the present phase-sampling telemeter illustrating the relationship of the several parts and units.

Figure 2 is a functional block diagram of the coder unit.

Figure 3 shows detailed embodiments of various forms of channel phase-modulators.

Figure 4 is a functional block diagram of the decoder.

Figure 5 is a chart illustrating the time sequence and relationship of the principal signals obtained in the operation of the decoder for one complete cycle of operation and also for expanded portions of parts of one cycle of operation.

Having mentioned above the purposes and functions of the phase-sampling telemeter, reference is made to the block diagram, Figure 1, which illustrates the functional relationship of the several major components or units of the telemetering system for accomplishing the desired results.

Within the coder **20** a continuous alternating voltage A of sinusoidal waveform is generated by either an inverter or oscillator unit **22** supplied to the taps on a

motor-driven mechanical commutator **26**, (*a*) directly as a reference phase voltage, and (*b*) through a plurality of parallel-connected channel phase modulators **23**, **24**, and **25**, each of which produces a variation in phase in accordance with variation of a sensing device carrying the information to be telemetered in that channel. As indicated in the drawing, reference phase voltage A and channel phase voltages B are preferably of the same amplitude. Connections are made on taps of the commutator so that for one revolution of the commutator brush, a group or frame of samples C of the sine wave voltage is delivered to coder output circuit **31**, the first and each alternate sample consisting of a number of cycles of the reference voltage, each except the last followed by a channel phase sample having approximately the same number of cycles but having its phase shifted in accordance with the information to be telemetered in the specific channel. A group of vacant commutator segments between the final and the first reference voltage taps provides a time gap between successive frames for the synchronization of the decoding equipment. The coder thus functions to produce successive frames consisting of samples of a reference voltage, each except the last followed by one of a sequence of a plurality of phase-shifted samples of said reference voltage, and a quiescent interval.

Transmission of the desired information may be effected by means of a wire loop from the coder to the decoder without additional equipment. In an alternate transmission method for fixed installations as well as for use in moving vehicles, ships, aircraft, and the like, a conventional radio link with additional radio transmission and receiving equipment is required.

In general the decoder **21** functions to separate the groups of information pulses from the reference pulses and to direct the information pulses from the various channels of the transmitter into the correct channel in the receiver. The decoder also provides with respect to each channel first pulses which are in phase with the pulses in the information channel and provides second pulses which are in phase with the pulses in the reference channel. Since the various signals are fed in serially, the reference signal appearing first in time, provisions must be made to "memorize" the reference time, so that the time of occurrence of the reference pulses and information pulses may be compared. Circuits are also provided for making this comparison and producing a D.-C. signal which is proportional to the phase shift of the pulses in the information channel.

Aside from the necessary power supplies, the decoder is composed of four major parts: (1) the synchronizer unit **27**, (2) the channel selector counter unit **28**, (3) the channel demodulator assembly **29**, and (4) channel output indicators or recorders **30**.

As shown in Figure 1, the synchronizer unit produces and feeds (*a*) to the channel selector counter unit **28**, unseparated channel synchronizing pulses D corresponding to the arrival of each channel wave train; (*b*) to the channel selector counter unit **28** a frame synchronizing reset pulse E for insuring that said unit operates in step with the commutator; (*c*) to the channel demodulator assembly a sequence of pulses F which are phase-locked to individual cycles of the reference signal generated with synchronizer unit **27**, and in turn are synchronized with the reference signal received from the transmitter; and (*d*) to the channel demodulator assembly a sequence of groups of pulses G, each group corresponding to a group received over the line **40**; that is, successive groups of reference and information pulses, and each pulse of each group corresponding to a separate cycle of the received waves.

The channel selector counter unit **28** is essentially an electronic commutator which functions in synchronism with the mechanical commutator **26** in the coder **20**. It provides for the channel demodulator assembly **29**, pulses D for synchronizing a delayed gate for selection of undistorted information pulses S (see Figures 4 and 5) within channel demodulator assembly **29**, and a gating pulse J for the individual channel selection from the composite signal pulse G. The gating pulses J are provided for each channel in turn in accordance with the sequence established by the connections on commutator **26** within the coder **20**.

The channel demodulator unit **29** functions to convert the magnitude of the phase modulation for each channel sample into a modulated D. C. signal K which is fed to the corresponding channel output indicator or recorder **30**.

Each channel output indicator or recorder **30** consists of a suitable indicating meter or oscillographic recorder.

Referring next to the block diagram of the coder **20**, shown in Figure 2, a sine wave form voltage of constant frequency is generated in an inverter or in a one-tube oscillator **22** (this being the only tube necessary to the coder) whose low impedance output is connected (*a*) to every fourth segment of a mechanical commutator **26** to provide a reference phase and (*b*) to a number of phase modulators **23**, **24**, and **25**, connected in parallel which are in turn connected to a corresponding number of instruments or sensing devices to produce phase modulation in proportion to the channel intelligence. The outputs of the modulators are connected to various commutator segments as shown. The wiper arm of the commutator thus transmits a repeating sequence or frame of bursts of sine wave voltage, each frame including channel phase samples 1, 2, . . . *n*, each preceded by a burst of cycles of the reference phase (see waveform C, Figure 1). Alternate segments of the commutator are left unconnected to provide a time gap between reference and channel phase samples. An extra long time gap is provided for proper frame synchronization at the decoder by omitting connections to several successive segments just prior to the reference phase connection preceding channel 1 segment of the commutator. The output from the commutator appears on line **40**.

Figure 3 shows a number of phase shift networks which may be utilized as the phase modulators **23**, **24**, and **25**, shown in Figure 2. The phase modulator of Figure 3(*a*) is controlled by a variable reactance, that of Figure 3(*b*) by a variable resistance. Figures 3(*c*) and (*d*) show modifications in the circuit of Figure 3(*b*) to provide for voltage control of phase. It may be shown that each of these networks produces phase shift without variation in attenuation of the signal (A Phase-Sampling Telemeter by M. G. Pawley and J. O. Dick, National Bureau of Standards Report 2020, published December 1952).

The networks of Figure 3 thus provide means for conversion of a varying voltage or varying mechanical displacement into a proportionate phase shift for application to one or more channels of the above-described telemetering coder **20**. Alternately a continuously rotatable phase shifter may be utilized where it is desired to transmit continuously rotating positional data.

Referring now to the block diagram of the decoder of Figure 4 for consideration of the operation of the preferred circuits for indicating or recording the magnitudes of phase shift for each of the channel samples with respect to the reference phase, the incoming signal C, indicated in Figure 1, is impressed on line **40** at the upper left of the figure to the synchronizer unit enclosed within a dotted line generally indicated by reference numeral **27**. The received signal is amplified in block designated **41** and squared in squaring amplifier **42** and delivered to cathode follower **43**, whose output wave form G terminates in three paths. Path **44** passes the pulse signals to the channel demodulator assembly shown in Fig. 4 as comprising the mechanism enclosed within a dotted line and generally indicated as **29**; path **45** leads to the circuitry provided for synchronizing a local oscillator within synchronizer unit **27** to supply a reference phase; and path **46** leads to the circuitry used for channel and frame syn-

chronization and for reference pulse gating. The signal in path **46** is fed to envelope detector **47** and then to squaring amplifier **48** to produce a voltage having a recurring square wave form, each positive excursion of the square wave corresponding alternately to a group of reference pulses and a group of information pulses (wave form L, Figure 5). In the interval between pulses, sawtooth generator **49** generates a voltage having a sawtooth wave form and an amplitude which is a function of the interval between pulses (wave form M, Figure 5). The wave forms C, L, M, E, N, D, and J are all on the same time scale, C being the controlling wave form.

It will be noted that the signal output of the coder and the corresponding signal input C (Figure 1) to the decoder for one complete frame is comprised alternately of reference phase samples and successive, separate respective channel phase samples, and concludes with a quiescent interval that occurs between the end of the last reference phase sample and the beginning of the first reference phase sample of the succeeding frame (wave form C, Figure 5). The quiescent interval at the end of each frame is utilized for the synchronization of the succeeding frame. During the quiescent interval the amplitude of the sawtooth wave form produced by generator **49** rises to a higher value than that produced during the much shorter intervals that exist between reference phase and channel phase samples. When the amplitude of the sawtooth voltage rises to such higher value, synchronizer separator **50** produces a pulse (wave form E) whose trailing edge marks the beginning of each frame and said pulse also (*a*) actuates over line **51** a delayed reference gate for the local oscillator phase synchronizer; (*b*) provides over line **52** a reset pulse for the flip-flop divider **54**, and (*c*) supplies over line **53** a reset pulse for the channel selector counter unit enclosed within a dotted line generally indicated **28**. In all three circuits to which the signal E is supplied it performs the same function, that is, to synchronize the start of each frame in the receiver with the start of each frame in the transmitter regardless of how badly they may have fallen out of synchronization during the previous frame.

The flip-flop divider **54** performs the function of separating the alternate reference phase samples and channel phase samples. Divider **54** is controlled by the signal L from the squaring amplifier **48** over line **55**. The output of divider **54** is taken through cathode follower **57** to provide a low impedance source to drive two outputs: (*a*) line **58** (wave form N) to the automatic reference oscillator synchronizing circuit, and (*b*) line **59** (wave form D) which provides the unseparated channel gate pulses (180 degrees out of phase with wave form N) for the channel selector counter unit **28**. It will be noted that the positive pulses of wave form N correspond to the interval from the beginning of a reference phase to the beginning of an information phase and the positive pulses of the wave form D correspond to the interval from the beginning of an information phase to the beginning of a reference phase.

Line **61**, which carries the driving pulse to actuate the automatic reference oscillator synchronizing circuit, may be switched, by means of switch **84**, to line **58** to provide synchronization when the reference phase sine wave is carried upon alternate commutator segments as shown in Figure 2, or switched to line **60** to permit synchronization once per frame when less accuracy of transmitted data is required. In the latter case the reference sine wave would be connected only to the first segment following the blank space of commutator **26** of Figure 2, leaving all alternate commutator segments free to carry information. The signal on line **61** (wave form N) in the former case under discussion is a square wave, the leading edge of which is used in triggering delay multivibrator **62** which in turn triggers the delayed gate multivibrator **63** to produce the wave form AA, Figure 5. The wave forms O, G, Z, Q, AA and BB are all on the same time scale which is expanded with respect to wave form C. The delay thus introduced permits the gate multivibrator **63** output (wave form AA) to select, in mixer **64**, a portion of the signal (wave form G) which is free of possible switching transients due to commutation. The pulse output of mixer **64** (wave form BB) provides an accurate reference time measurement for the transmitted reference sine wave and is used, after being shaped in pulse shaper **65** (wave form U) to recreate a continuous reference sine wave in the automatic synchronizing loop that comprises blocks **67, 71, 72, 73, 74, 75, 78,** and **79**. The wave forms T, U, V, and W all have the same time base which is expanded with respect to wave form O. In the operation of the synchronizing loop the phase of the sine wave output of the local reference or master oscillator **74**, as embodied in the sawtooth (wave form V) is compared in phase comparator **67** with the phase of the selected group of reference phase pulses (wave form U). The output from the phase comparator **67** is a squence of pulses (wave form W) which is integrated in the storage network **71** to produce a direct voltage whose amplitude and polarity is a measure of the phase error between the output from the coder oscillator **22** of Figure 2 and the signal from the decoder reference or master oscillator **74**. The output voltage from the phase comparator **67** is applied, through switch **83** and electrometer circuit **72**, to the grid of the reactance tube modulator **73** which controls the frequency of the master oscillator **74**. Storage network **71** is required to store the bias voltage obtained from phase comparator **67** during the phase comparison period over the long quiescent interval during which no phase correction pulses are received. Electrometer **72** is employed to eliminate leakage of the stored bias charge from storage network **71** during the quiescent interval between reference phase pulse groups. Master oscillator **74** most be capable of a very high degree of stability in order that phase error due to oscillator drift during the quiescent interval may be minimized. The output of master oscillator **74** is used to trigger multivibrator **75**. The output of multivibrator **75** is a narrow pulse, one for each cycle of master oscillator **74**, which is utilized for two purposes: (*a*) line **76** carries the multivibrator pulse to sawtooth generator **78**. The sawtooth voltage wave (wave form V) is fed by means of cathode follower **79**, which serves as an impedance matching device, over line **80** to phase comparator **67** where the phase comparison is made as previously explained; (*b*) the second output of multivibrator **75** passes over line **77** through inverter **81** to provide the reference phase pulses F, needed in the channel demodulator assembly **29** for the purpose of decoding channel information. Switch **83**, located in output line **68** of phase comparator **67**, is used in the manual position to enable adjustment of the oscillator **74** frequency to conform to an optimum operating bias on the reactance modulator **73**.

The channel selector counter unit **28** has two inputs, (*a*) the pulse from the flip-flop divider **54** (wave form D) in which the leading edge or positive transition of each square wave corresponds to the start of each channel information sample, and (*b*) the separated synchronizer pulse (wave form E).

In the following discussion reference will be made to wave forms O′, G′, P (D expanded), GG (J expanded), R and S. These wave forms all have the same time base which is expanded over the wave form C by the same amount as wave form O. However, the time base of O′ has been shifted with respect to O and the starting time for these wave forms is the beginning of the information signal in channel 1 rather than the beginning of the reference signal immediately preceding channel 1.

The flip-flop divider **54** output (wave form P) is introduced over line **59** through isolating cathode follower **85** to squaring amplifier **86**. The output of squaring amplifier **86** follows two paths: (*a*) line **88** is connected to cathode follower **89** whose output is required in the

channel demodulator assembly **29**; (*b*) line **87** is connected to pulse generator **90** which is used to shape the squared wave (wave form D) into the very sharp pulses needed to drive in parallel, over lines **91, 92, 93, 94, 95,** the electronic counter units **96, 97, 98, 99,** said counter units being connected so that the successive counters fire in sequence and recycle in ring counter fashion. In this manner a square positive pulse or gate (wave form J) is made available at the output of each counter **96, 97, 98, 99** coincidence with occurrence of the corresponding channel information sample and thus provides a gate to enable separation of the information for that channel from the composite signal. The output gate pulse (wave form J or GG) from each counter is connected to the appropriate channel demodulator for signal processing; for instance, as shown in Figure 4, output from counter 1 is connected to channel demodulator unit 1, which is comprised of the circuits and apparatus generally indicated by the heavily outlined blocks **109, 117, 119, 121, 125, 130, 131** and indicator or recorder **30**. As indicated by the arrow-terminated connections in Fig. 4, there is thus provided separate channel demodulator units within channel demodulator assembly **29**, corresponding to each of the counters **96–99** respectively.

The channel demodulator assembly **29** performs two basic functions in the process of decoding: (*a*) the separation of the proper group of information pulses corresponding to the individual channels from the composite signal, and (*b*) the recovery of the transmitted channel information from the separated groups of information pulses. The selection of the group of information pulses (in this case for channel 1) is accomplished in mixer **109**. Line **102** carries the input gate pulse (wave form GG) from the proper counter **96** of the channel selector counter unit **28**. Line **100** carries the square wave (wave form D) from the flip-flop divider **54** through **57, 59, 85, 86, 88, 89,** to the channel demodulator assembly **29**. The leading edge of these channel synchronizer pulses, marking the start of the commutated information periods, is applied to the input of delay multivibrator **106**, the output of which drives gate multivibrator **107** to generate a gating pulse (wave form R) which is delayed in time in order to select a portion of the signal free of commutation switching transients. The latter pulse is carried through line **108** to mixer **109**, and also to each additional channel mixer. For channel 1 the third input to mixer **109** is the composite signal (see wave form G') which is introduced on line **44**. Thus, the coincidence of the delayed gate (wave form R) and a channel selector gate pulse (wave form GG) permits mixer **109** to pass a selected group of pulses (wave form S) which convey the information transmitted in channel 1. Similarly, information in other channels is processed in the additional channel demodulators. Since the counters **96, 97,** etc. are stepped during each positive excursion of the wave form D, the pulse J lasts not only for the duration of the information pulses in channel 1 but also through the succeeding interval when the next group of reference pulses are received. Since only the information pulses should be gated, the wave form R is used, in conjunction with wave form J, to narrow the gating time to the duration of the pulses in the information channel only.

Reference pulses (wave form F) are carried from the synchronizer unit **27** over line **82** and introduced into channel demodulator assembly **29** through coupling diode **111** to trigger the phantastron sawtooth generator **112**. The pulses of the wave form F occur continually during the operation of the system; that is, both during reference periods and information periods. Each pulse occurs at a time corresponding to the beginning of a positive excursion of each cycle in the reference signal. The synchronizing circuits in unit **27** maintain this relationship even during the periods when the reference signal is not being received. Therefore the F pulses establish the zero phase shift condition, the circuits for producing the F pulses providing therefore the necessary memory features of the system. The scale of the F, DD, EE, and FF pulses is the same as that of the T pulses. The sawtooth output (wave form DD) of phantastron **112** is taken from the cathode follower **113**, which is also a part of the phantastron **112** feedback circuit, and carried over lines **115** and **116** to all channel demodulators. As previously indicated, blocks in Figure 4 outlined in heavy lines are circuits applying particularly to channel 1, but typical to those for the other channels. The negative excursion of the wave form DD begins at a time corresponding to zero phase shift and continues to go negative for a period which covers the maximum phase shift of a single cycle of the information signal. The signal DD then returns to its maximum amplitude before the next pulse F; thereby providing a separate sawtooth wave for comparison with each pulse of the signal EE produced by individual cycles of the information signal. The phantastron output (wave form DD, Figure 5) line **115** is coupled to cathode follower **117**. In this stage the proper direct voltage is added to the phantastron sawtooth voltage (wave form DD) to produce zero output from the channel demodulator unit for the corresponding channel zero information input. The output of cathode follower **117** (wave form DD) is connected directly to the cathode K_1 of the charge tube **121**. The control grid G_1 of charge tube **121** is normally biased negatively so that the tube is non-conducting regardless of the negative excursion of the cathode in following the negative going sawtooth wave form (wave form DD) from the phantastron **112**. The plate P_1 of charge tube **121** is connected to storage capacitor **124** and also to discharge tube **125** and discharge clamp **130**.

Immediately prior to the arrival of the selected group of information pulses (wave form S) the decoder reset pulse (wave form FF) actuates discharge tube **125** which removes any previous charge on storage capacitor **124** and, through the action of discharge clamp **130**, maintains a charge potential of zero volts upon storage capacitor **124** in preparation for the anticipated information. The selected group of information pulses (wave form S) is shaped in multivibrator **119** into the uniform square pulses of wave form EE and applied to the control grid G_1 of the charge tube **121** where they allow said tube to conduct only for the duration of one pulse. Owing to the size of the storage capacitor **124** it is impossible to charge it fully during a single charging period. Thus the full information charge related to a single channel sample is accumulated on the storage capacitor during the corresponding series of shaped pulses (wave form EE). Since the phantastron sawtooth generator **112** is triggered by the reference phase pulse (wave form F) the point of triggering corresponds to zero phase shift. Any delay of timing or shift in phase of the selected channel information pulses corresponds to the transmitted information for that channel. This resulting delay allows the linearly decreasing sawtooth voltage wave form (wave form DD) to accurately convert the phase information into analog information in the charging circuitry. The charge thus established upon storage capacitor **124** through the action of charge tube **121** is fed to one control grid of metering tube **131** which consists of a balanced cathode follower wherein both sections of a dual triode are used as symmetrical cathode followers, the grid of one section being connected to storage capacitor **124** to meter the information, while the second section is used as a zero balance. This configuration reduces the zero drift effects due to changes of filament voltage and to other variations in cathode emission to a minimum.

A meter, oscillograph, or other suitable data-recording device **30** is connected between the cathode outputs of the two cathode followers of metering tube **131** to provide the output for the channel demodulator unit. The

transient pulse shown in the output voltage wave form (wave form K) is removed by integration in the metering or recording device; that is, the meter or recorder provides an output which is proportional to the area under the curve K and will not follow the wave form. Each complex pulse of wave form K corresponds to the information produced in a separate channel of the transmitter unit.

It can be seen from the above that a very simple and compact coder unit is provided by the present invention. Only one electron tube is required, thereby providing a rugged unit which may be easily maintained. Although the decoder unit is somewhat complex it will usually be situated at a place where skilled personnel are available to service the equipment.

The various circuits included in the blocks of Figure 4 are conventional and are in no wise novel. However, the complete circuitry may be found in the aforementioned article.

It will be apparent that the embodiments shown are only exemplary and that various modifications can be made in construction and arrangement within the scope of my invention as defined in the appended claims.

What is claimed is:

1. A phase-sampling telemeter system comprising a source of a sinusoidally varying voltage, first means responsive to said source for generating a plurality of discrete phase-shifted output voltages respectively in accordance with conditions to be sensed, second means for sequentially transmitting alternately a number of cycles of the sinusoidally varying voltage as a reference phase and a successive discrete one of the phase-shifted voltages serially to a remote location, an oscillator having the same frequency as said source voltage located at the remote location, third means responsive to said reference phase sinusoidally varying voltage for synchronizing said oscillator with said source voltage, fourth means for producing a series of discrete pulses in phase with the respective phase-shifted voltages; and means for comparing the phase displacement between the output pulses of said oscillator and of said fourth means.

2. A phase-sampling telemeter comprising a source of a continuous sine wave reference voltage, a plurality of means responsive to said source for generating a plurality of discrete phase-shifted output voltages respectively in accordance with conditions to be sensed, means for sequentially transmitting to a remote location a series of frames of signals, each frame including a number of distinct groups of cycles of the reference voltage and a number of distinct groups of cycles of the phase-shifted voltages, each successive discrete phase-shifted voltage interleafing the groups of cycles of said reference voltages, an oscillator, located at the remote location, having the same frequency as said source, means responsive to said reference voltage to synchronize said oscillator with said source voltage, means for producing pulses corresponding respectively to the individual cycles of the phase-shifted voltages and means for comparing the phase of the last-mentioned pulses with the phase of the output voltage of said oscillator.

3. A phase-sampling telemeter comprising a source of a single frequency reference voltage, a plurality of phase-modulating means, there being one for each channel of information to be transmitted, each of said phase-modulating means being connected to receive the output of said source, commutator means for producing a series of frames made up of a number of groups of signals, the first and each alternate group of signals consisting of a number of cycles of the reference voltage, each reference voltage group being followed by a number of cycles of a phase-modulated signal, each phase-modulated signal in a frame representing the information from a phase-modulating means in a different channel, means for transmitting the signals to a remote location, an oscillator, at the remote location, having the same frequency as said source, means responsive to the output of said oscillator and to the reference voltage signal to synchronize said oscillator with said source, a ring counter having a number of stages equal to the number of channels of information transmitted, means for stepping said ring counter at the beginning of the information signal from each channel and a plurality of channel demodulator units, one for each channel, each unit comprising a gating means connected to receive the output of the counter stage corresponding to the channel with which the particular gating means is associated, means, including said gating means, for producing a pulse corresponding to each cycle of the information signal of that channel and means for comparing the phase of the output of said last-mentioned means with the output of said oscillator.

4. A phase-sampling telemeter comprising a source of a single frequency reference voltage, a plurality of phase-modulating means, there being one for each channel of information to be transmitted, each of said phase-modulating means being connected to receive the output of said source and adapted to generate a respective discrete phase-modulated information signal, commutator means for producing a series of frames made up of a number of groups of signals, the first and each alternate group of signals consisting of a number of cycles of the reference voltage, each reference voltage group being followed by a number of cycles of a different one of said discrete phase-modulated information signals, each phase-modulated signal in a frame representing the information from a phase-modulating means in a different channel, means for transmitting the signals to a remote location, means, located at the remote location, for producing a first signal once each cycle of the reference signal in phase with the reference signal, a plurality of channel demodulator units, one for each channel of information, each unit comprising means for producing a second signal once each cycle of the information signal of that channel and in phase with the information signal, and means for comparing the phase of the first and second signals to produce a signal indicative of the phase displacement of the phase-modulated signals.

5. A phase-sampling telemeter, comprising a source of a single-frequency, sinusoidal, reference voltage, a plurality of phase-modulating means, there being one for each channel of information to be transmitted, each of said phase-modulating means being connected to receive the output of said source, commutator means for produring a series of frames made up of a number of groups of signals, the first and each alternate group of signals consisting of a number of cycles of the reference voltage, each reference voltage group being followed by a number of cycles of a phase-modulated signal, each phase-modulated signal in a frame representing the information from a phase-modulating means in a different channel, means for transmitting the signals to a remote location, means located at the remote location, for producing a first signal once each cycle of the information signal of that channel and in phase with the information signal, means for comparing the phase of the first and second signals to produce a signal indicative of the phase displacement of these signals, means for producing a signal at the beginning of each information signal, and counting means responsive to the output of said last-mentioned means for rendering operative the channel demodulating unit which corresponds to the information channel transmitting.

6. A phase-sampling telemeter, comprising a source of a continuous sine wave reference voltage, a plurality of means responsive to said source for generating a plurality of discrete phase-shifted output voltages respectively in accordance with conditions to be sensed, means for sequentially transmitting to a remote location a series of frames of signals, each frame including a number of distinct groups of cycles of the reference voltage, and a number of distinct groups of cycles of the phase-shifted voltages, each successive discrete phase-shifted voltage

interleafing the groups of cycles of said reference voltages, means, located at the remote location, for producing a first signal once each cycle of the reference signal in phase with the reference voltage signal, a plurality of channel demodulator units responsive to said reference voltage and to successive ones of said discrete phase-shifted voltages respectively, one for each channel of information, each unit comprising means for producing a second signal once each cycle of the information signal of that channel and in phase with the information signal, and means for comparing the phase of the first and second signals to produce a signal indicative of the phase displacement of these signals.

7. A phase-sampling telemeter, comprising a first oscillator for producing a sinusoidal voltage, a plurality of phase-modulating means connected to receive the output of said first oscillator, each of said phase-modulating means varying the phase of the sinusoidal voltage in accordance with a condition sensed by said phase-modulating means, a commutating means having a plurality of input circuits and one output circuit, at least one of said input circuits being connected to the output of said first oscillator and the output of each phase-modulating means being connected to a separate input circuit, means for connecting said input circuits one at a time sequentially to said output circuit, means for connecting said output circuit with a remote location, a second oscillator having the same frequency as said first oscillator, means responsive to the output of said first oscillator for synchronizing said second oscillator with said first oscillator, a plurality of means, each of which is responsive to the output of a different phase-modulating means for producing a series of pulses in phase with the phase-shifted signals, and means for comparing the timing of said pulses to the time of the output pulses from said second oscillator to determine the phase shift of the phase-shifted pulses.

8. A phase-sampling telemeter comprising a first oscillator for producing a sinusoidal voltage, a plurality of phase-modulating means connected to receive the output of said first oscillator, each of said phase-modulating means varying the phase of the sinusoidal voltage in

accordance with a condition sensed by said phase-modulating means, a commutating means having a plurality of input circuits and one output circuit, at least one of said input circuits being connected to the output of said first oscillator and the output of each phase-modulating means being connected to a separate input circuit, means for connecting said input circuits sequentially one at a time to said output circuit, means for connecting said output circuit with a remote location, a second oscillator, located at the remote location, having the same frequency as said first oscillator, means responsive to the output of said first oscillator and said second oscillator to synchronize said second oscillator with said first oscillator, a ring counter having a number of stages equal to the number of phase-modulating means, means for stepping said counter at the beginning of the reception of each phase-modulated signal, a plurality of demodulating units, each unit comprising a gating means having a first input connected to receive the output of said output circuit and a gating input connected to receive the output of the counter stage which is energized at the time that the phase-modulating means with which said gating unit is associated is transmitting, said gating unit thereby passing only those signals which correspond to the channel with which the particular demodulator unit is associated, means responsive to the output of said gating unit for producing a pulse corresponding to each cycle of the phase-shifted signal and in phase with said signal, and means for comparing the phase of said pulses with the output of said second oscillator.

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