Twinplex and Twinmode Radiotelegraph Systems

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DURING the past ten years, the use of frequency-shift transmission has been steadily increasing to the point where, today, we find a majority of the international radio circuits using this system for either Morse code or automatic printer operation, with a predominant trend toward the latter. The reliability afforded by frequency-shift transmission has permitted the use of several types of time- and frequency-division multiplex systems to handle increasing traffic loads. On circuits where the requirements are for two channels, the basic system herein described will provide a high grade of service combined with a maximum of flexibility and at a minimum of cost.

This system, retaining the advantage derived from frequency shift, has been developed to the stage where it is in daily operation on several long-haul radio circuits. The basic principle of the system, which is called Twinplex, may be extended to provide 4 or more channels, using single-sideband or subcarrier modulation methods. At present, its greatest utility is in converting existing single-channel frequency-shift radio circuits to two-channel, nonsynchronous, Morse, printer, or mixed-code operation. Alternatively, the Twinplex system may be used to transmit one channel of 3-element cable code. This latter technique has found a rather-important application in the direct connection of radio circuits to ocean cable systems.

The Twinplex system is based on the proposition that two 2-element mark–space channels may be combined to form on the frequency scale a single 4-element channel wherein each of 4 frequencies represents one of the 4 possible mark–space combinations shown in Table 1.

TABLE 1

Mark–Space Combinations for Two Channels

Channel *A*	Channel *B*	Frequency
Mark	Mark	*F1*
Mark	Space	*F2*
Space	Mark	*F3*
Space	Space	*F4*

At the present time, 400-cycle-per-second separation is used between each of the 4 frequencies, making a total frequency shift of 1200 cycles. Total bandwidth, including keying sidebands, is confined to 1700 cycles with 60-word-per-minute printers keying on both channels. The rate of transition between the 4 signaling conditions has been held to that prevailing for standard operation on a single-channel basis so that the only increase in occupied bandwidth is due to the increase in over-all prime frequency shift. Compared to the standard 850-cycle shift for a single channel, the additional bandwidth for 2-channel Twinplex will be only 350 cycles.

Extensive field testing and daily operation of many long-distance circuits have shown on the basis of error counts that, generally speaking, 2-channel Twinplex is equally effective on any radio circuit that normally supported a single-channel frequency-shift printer circuit.

In order to convert to Twinplex operation, one small combiner unit is added at the transmitting station and three pieces of conversion equipment at the receiving station. The conversion equipment has been designed to fit into the space vacated by single-channel equipment. This results in great economy of space and permits existing installations to be easily modified for 2-channel operation.

Finally, the great flexibility of operation cannot be overemphasized. Full freedom is allowed the traffic department in utilizing the available channels. For example, a 60-word-per-minute printer may be on one channel and a 75-word-per-minute printer on the second or a printer and Morse combination may be used. Branch-office extensions offer no problem and forked circuits may be efficiently handled. In international radio traffic operations, differences in printer speeds, codes, and operating procedures are likely to be with us for some time to come. The basic Twinplex system would seem to offer the most economical means of doubling traffic-handling capacity while retaining the inherent advantages of single-channel frequency-shift transmission.

1. *Theory of Twinplex Signaling*

The Twinplex concept of 2-channel signaling involves certain transitional phenomena that must be considered in the design of effective equipment using this principle of operation.

When two 2-element channels are combined, there are only 4 combinations possible and these may be represented as a 4-element channel on the frequency scale. Such a set of signaling conditions is shown in Table 2.

TABLE 2

TWINPLEX SIGNALING CONDITIONS

Input Keying Channels		Relative Combined Output in Volts	Transmitted Carrier Frequency in Cycles	Detected Receiver Frequency in Cycles	Output Tone-Keyed Channels	
A	*B*				*A*	*B*
Mark	Mark	0	$F1 = F_c + 600$	1950	Mark	Mark
Mark	Space	1	$F2 = F_c + 200$	2350	Mark	Space
Space	Mark	2	$F3 = F_c - 200$	2750	Space	Mark
Space	Space	3	$F4 = F_c - 600$	3150	Space	Space

It is interesting to note at this point that to extend this type of grouping beyond two channels would involve transitions between so many frequencies as to make the design of the equipment highly impractical. The relationship which holds is

$$F_N = 2^N, \quad (1)$$

where F_N is the number of frequencies and N is the number of channels.

Three channels would involve 8 frequencies, four channels 16, and so on. However, multiples of the 2-channel Twinplex grouping applied, for example, as a multiplex group on a single-sideband transmitter would be quite economical of frequency spectrum and offer a 3-decibel over-all power gain due to the fact that the available power is distributed among half the number of frequencies that would be required for conventional mark–space keying of each channel.

In the case of nonsynchronized keying on the present 2-channel system, the carrier frequency is shifted among 4 values at completely random intervals. For example, 10 percent of a mark pulse on channel *A* may take place on *F1* and 90 percent on *F2*, or any other division of the mark may occur. The receiving circuit arrangements are such that whenever a transition occurs on one channel, the signaling condition on the other channel is undisturbed except during actual transition from mark to space on the first channel. This holds true for all the possible signal combinations that may occur. However, when keying takes place between two frequencies such as *F1* and *F3* and the output of a bandpass filter centered on *F2* is observed on an oscilloscope, it will be seen that a "pip" of energy comes through during each transition between *F1* and *F3* (Figure 1). The amplitude of these pips is dependent, mainly, on the rate of transition between *F1* and *F3* and the attenuation characteristics of the *F2* filter. During signaling, the transition rate and the bandpass-filter characteristics are fixed and so the amplitude of the pip is fixed in relation to the main signaling pulse. In the design of a practical system, the pip amplitude has been held to about $\frac{1}{4}$ of the main pulse amplitude. To bring it down further would

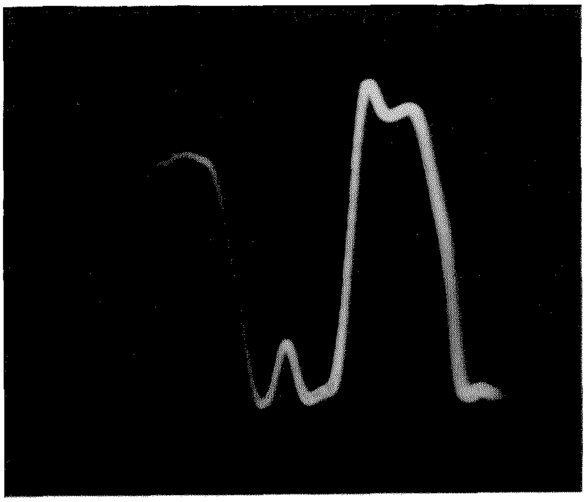


Figure 1—Transitional pip through *F2* filter at bottom.

require a much faster transition rate and thereby increase the keying sidebands. In present Twinplex equipment, the mark-to-space transition rate that prevailed with single-channel frequency-shift keying has been maintained.

A second effect called "splitting," takes place when a mark–space transition occurs within a mark pulse causing part of the pulse to occur on one frequency and the remainder on a second frequency. If we look at the recombined mark at the output of a low-pass filter, a split will be observed at the point within the mark where the transition occurred. The amplitude of the split is also about $\frac{1}{4}$ of the main pulse amplitude and is governed by the same factors as the pip. Figure 2 shows a recombined mark pulse on channel-*B* low-pass filter output. The split at the top is caused by a mark-to-space transition on *A*.

The circuits following the receiving filters and signal rectifiers are designed to work in the area that lies between the split from the top and the pip from the bottom of the pulse.

To obtain a wide operating margin, the tone pulses are amplified to a rather high voltage level. The pips and splits will be amplified proportionately but, in terms of volts lying in between, we gain operating margin. The filtered tone pulses are then rectified and passed through suitable low-pass filters before being applied to the grid of a direct-current amplifier that is adjusted to key to mark several volts above the half-amplitude point of the rectified pulse and to key to space several volts below this point. By careful design and adjustment, the direct-current amplifiers may be made to key within less than one-half the margin available between the pip and split regions.

The mark–space signaling combinations of the system are such that both splits and pips may occur on channel *B*, but splits only can occur on channel *A*. This might at first seem to indicate that the failure point of channel *B* would occur at a considerably higher signal-to-noise ratio than for channel *A*. Measurements of the signal-to-noise ratio show that channels *A* and *B* fail at very nearly the same level, regardless of whether the opposite channel is keying or not. When the signal-to-random-noise ratio becomes unfavorable in the limiter, the energy distribution of the limiter output is spread more and more over the entire input bandpass region. Consequently, there is less output available on the desired signaling frequencies. This causes the familiar depression towards zero of the desired signal at the output of the mark-channeling filter and, if deep enough, subsequent failure of the signal. It has been observed that this depression of the signal due to noise tends to mask the inherent pips and splits somewhat before the actual failure point occurs. The breaking point is very sharp and seems to occur on single-channel keying within less than 2 decibels after keying failure with both channels has occurred. Measurements of the signal-to-noise ratio have been made using receiver-tube hiss and thermal agitation as a noise source. These measurements indicate that failure of the tone output of *A* and *B* channels occurs only after the noise level at the converter input is raised to 6 to 8 decibels above the signal level.

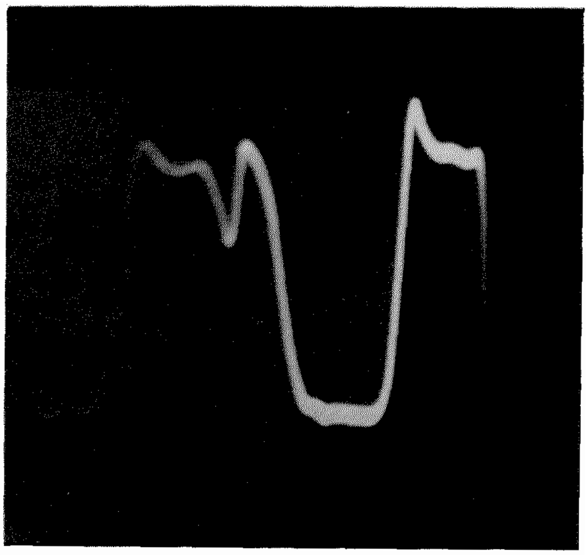


Figure 2—Recombined mark pulse of *B* channel showing split.

2. *Bandwidth and Keying Characteristics*

The total frequency shift of 1200 cycles is centered about the assigned carrier frequency so that mark–mark is 600 cycles plus, space–space 600 cycles minus and the two intermediates 200 cycles plus (mark–space) and 200 cycles minus (space–mark). Keying sidebands are determined by the transition rate from marking to spacing intervals, sometimes called the slope of the keying. In frequency-shift transmission, the transition rate may be closely controlled by choice of the proper time-constant in the grid circuit of the reactance-tube modulator, through which the keying pulses must pass. For standard single-channel operation, a resistance–capacitance filter providing a time-constant of about 200 microseconds has been used to handle keying speeds up to 240 dot-cycles per second without undue biasing of the pulses. For Twinplex operation, the same filtering has been retained so that the bandwidth will increase only by the amount of additional frequency shift, or 350 cycles, when compared to standard 850-cycle single-channel transmission. The over-all Twinplex system allows for a maximum keying speed of about 50 dot-cycles per second per channel with the limitation being placed on the receiving-end filters in order to circumvent the pips and splits that are inherent in this method of transmission. When two 60-word-per-minute 5-unit printers are used, operating margins of 65 to 75 points are normally obtained and regeneration is not required. This is equivalent to the performance obtained on standard single-channel circuits. It is expected that the present system will handle two 100-word-per-minute printers, when these become available.

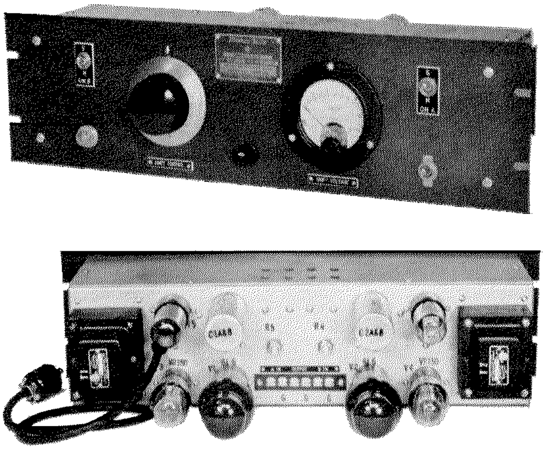


Figure 3—Front and rear views of the Twinplex combiner.

In ocean-cable-code transmission, a 3-element code consisting of dot, dash, and neutral elements is used, corresponding to positive current, negative current, and no current through the cable. On a frequency basis, three signal frequencies are required for its transmission. Before the development of the Twinplex system, it was necessary to resort to manual transcription or mechanical reperforation equipment for interconnecting ocean cable and radio networks. For cable-code transmission using Twinplex, only three frequencies are used namely, mark–mark for neutral, mark–space for dot, and space–mark for dash, making a total frequency shift of 800 cycles. Cable-code keying speed in dot-cycles per second is slow compared to Morse or 5-unit printer code. Maximum operating speed of the cables connecting with one of the Twinplex radio circuits, is about 1200 center holes per minute on the perforated tape. This is equivalent to 20 bauds or 10 dot-cycles per second. However, the information or message content of cable code, requiring about 23 center holes per word, is roughly twice that of international Morse so that traffic flowing at a speed of 10 dot-cycles per second is equivalent to about 53 words per minute in Morse.

In an intermixed network of cable and radio circuits, the use of Twinplex has greatly simplified the speedy handling of traffic by eliminating mechanical reperforation and attendant maintenance problems, while at the same time improving operating efficiency.

3. Transmitting Apparatus

One small unit, the Twinplex combiner, is required in addition to that already at hand for standard single-channel frequency-shift transmission. Front and rear views are shown in Figure 3. The combiner has two direct-current channel inputs and one closely regulated direct-current output, which is used to bias the reactance-tube grid in a frequency-shift exciter. The two inputs are keyed from standard tone rectifiers and ignore any voltage fluctuations therein above the threshold level required to key the combiner unit, thus isolating the frequency-shift-exciter reactance circuit from any variable conditions existing on the keying channels.

Essentially, the combiner consists of two small well-regulated power supplies in which fractions of the individual voltage sources are triggered off across individual load resistors by two keyer tubes. One source is adjusted to produce twice the output voltage of the other. These resistors are connected in series across a third resistor, which forms the output load impedance. When the latter resistor is very large compared to the individual load resistors, the voltages will add up to a sufficiently accurate degree for all practical purposes. Figure 4 shows the principle of operation used in the combiner. When the voltage across *R1* is, say, 1 volt and that across *R2* is 2 volts, the voltage across *R3* is very close to 3 volts. With a 200:1 ratio of *R3* to $(R1+R2)$, it is actually 2.98 volts. Negligible current is drawn by the reactance-tube input circuit so the 1, 2, 3 relationship may be closely maintained.

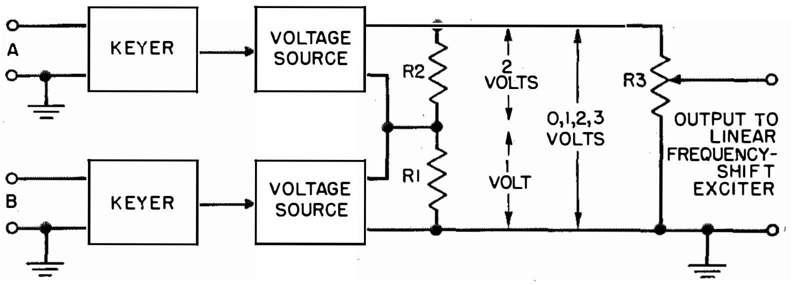


Figure 4—Principle of combining two keying channels. $R1 = R2$ and $R3 = 200\ R1$. The output voltages and transmitted frequencies are given in Table 2.

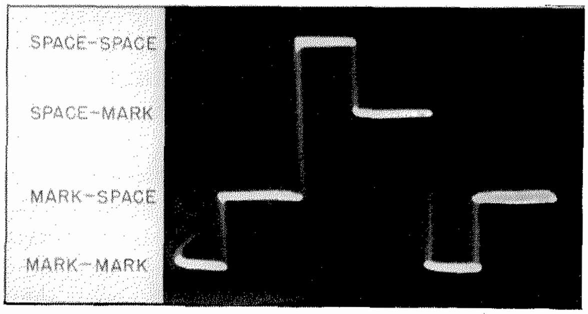


Figure 5—The 4-step keying pattern.

The combiner operates as follows. With keyer tubes *A* and *B* both cut off, zero volts output (mark–mark); *A* cut off and *B* conducting, 1 volt output (mark–space); *A* conducting and *B* cut off, 2 volts output (space–mark); *A* and *B* both conducting, 3 volts output (space–space). Over-all frequency shift is controlled by the voltage divider *R3*, with intermediate shifts remaining proportional at any setting.

The frequency-shift exciter associated with the combiner must shift linearily to at least 1200 cycles in order that the transmitted frequencies will be exactly proportional to the combiner output voltages. Also, the stability must be high so each of the 4 frequencies may be held to within ±50 cycles at a carrier of 20 megacycles over operational periods of 8 hours or longer. This degree of frequency stability has been achieved by improvements in the 200-kilocycle oscillator circuit and in the characteristics of the temperature-control oven of existing frequency-shift exciters. Figure 5 shows the 4-step keying pattern at the combiner output produced when the two channels are keyed at random.

4. Receiving Apparatus

The receiving apparatus consists of the Twinplex converter, tuning monitor, and dual tone keyer, which together occupy a total panel space of 17½ inches, making it possible to mount these units in the same rack space required by certain types of single-channel dual-diversity frequency-shift conversion equipments (Figure 6). The

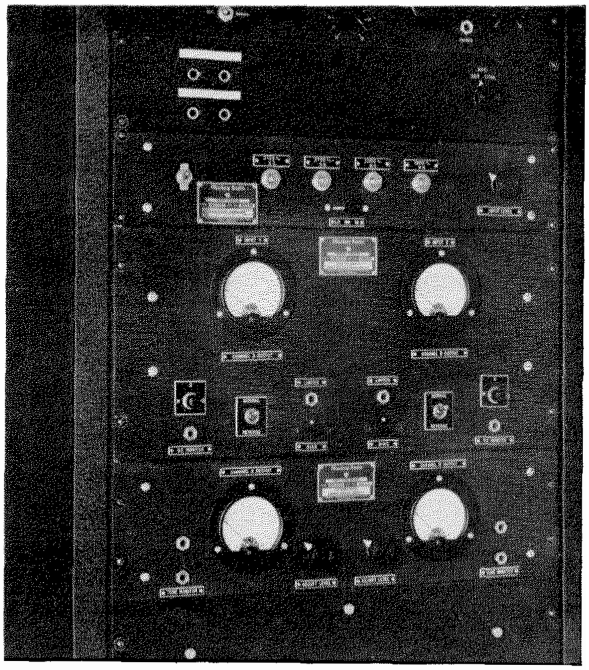


Figure 6—Twinplex receiving terminal apparatus.

Twinplex converter is a dual-diversity unit that accepts the 4 audio frequencies from the two radio receivers and, after amplitude limiting, separates them into the *A* and *B* channels. The frequency separation is accomplished by 3 bandpass filters having bandwidths of ±100 cycles about center frequencies of 1950 (mark–mark), 2350 (mark–space), and 2750 (space–mark) cycles as may be seen in Figure 7. The fourth frequency, 3150 cycles (space–space) is not passed through any filter. This frequency holds down the limiter output to the exclusion of noise, and since it does not pass on to the diode signal rectifiers, both channels *A* and *B* go to the space condition. The rectified output of the 1950-cycle (mark–mark) filter keys both channels *A* and *B* to mark, 2350 cycles (mark–space) keys *A* to mark and *B* to space, and 2750 cycles (space–mark) keys *A* to space and *B* to mark. For dual-diversity operation, two identical transient-free limiter channels, saturating at an input of −40 decibels, are used to drive the two sets of three filters. These filters are of a high-impedance type each working from the plate circuit of a triode and terminating in 50,000 ohms. The voltage gain obtained in the filter simplifies the equipment considerably by eliminating additional amplifier stages. By rectifying at a relatively high signal voltage level in the diversity-connected diodes, a wider operating range for the following direct-current amplifiers is obtained.

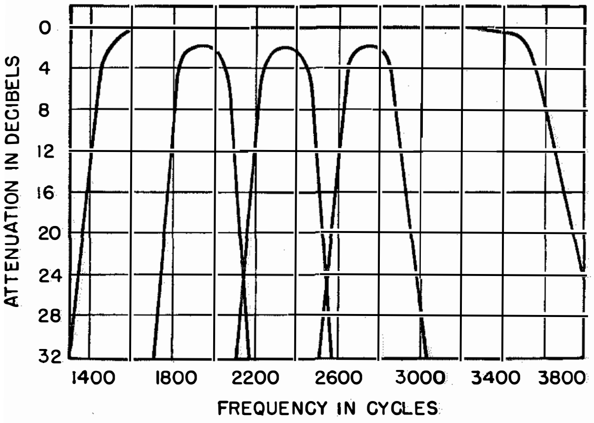


Figure 7—Characteristics of the receiving filters and of the input bandpass filter.

Differential rectification is not used with this system but due to careful consideration of the basic factors affecting the failure point, the system is on a par with several types of single-channel equipment that use differential rectification. The output of the signal-rectifying diodes is passed through a separate low-pass filter, the characteristics of which are shown in Figure 8, for the *A* and *B* channels and then to the first grid of a 2-stage direct-current amplifier, whose operating threshold may be adjusted so that keying from mark to space takes place in one-half the margin available between the pip and split regions of the pulse. The direct-current output of the converter keys a dual tone keyer for transmission of the signals to the central office over regional facilities. Switches are provided on the converter for reversing the mark–space condition on either channel and for placing static test signals on the line. Jacks are provided for monitoring the limiter, bandpass filter, low-pass filter, and tone channel outputs so that step-by-step maintenance is simplified.

A tuning monitor on a $3\frac{1}{2}$-inch panel is provided as an aid in adjusting the common-oscillator injection frequency to produce the 4 proper audio frequencies for driving the converter. This unit consists essentially of an input amplifier and 4 high-*Q* tuned circuits, each operating in the plate circuit of a triode tube. Across each circuit, a neon indicating lamp is connected, which glows

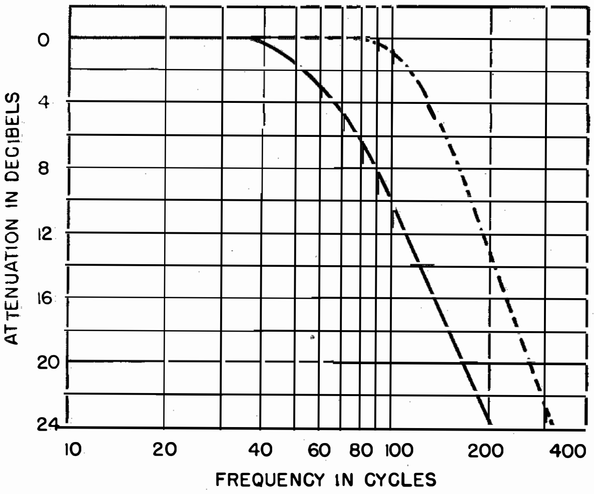


Figure 8—Either of the two characteristics shown may be selected for the low-pass filter through which the rectified signal currents flow.

only when the correct frequency, ±50 cycles, is present. Thus, when both channels are keying, all 4 lights will glow on and off, intermittently. When channel *A* keys and *B* is on mark, the mark–mark (1950-cycle) and space–mark (2750-cycle) lights, only, will glow and similarly the lights will follow all other keying combinations. In addition, the mark–mark (1950-cycle) circuit is provided with a high–low switch that cuts in capacitors for tuning the circuit to 75 cycles higher and 75 cycles lower than normal. By manipulation of this switch while tuning the common-oscillator frequency control, the audio frequencies may be adjusted within ±10 cycles of their proper values. Frequency drift of the transmitter or receiver oscillator may be detected and corrected before keying failures occur in the output of the converter.

The dual tone keyer occupies 5¼ inches of panel space. It uses two resistance–capacitance oscillators of the phase-shift type, two phase inverters, and two push-pull amplifiers that are keyed in the cathode circuit by the converter direct-current output channels. Tone output of each channel is adjustable to 0 decibels, which is 6 milliwatts into 600 ohms impedance.

These three units comprise the Twinplex receiver conversion equipment. They may be mounted in a dual-diversity receiving bay together with two radio receivers, a common oscillator unit, and a terminal power supply as may be seen in Figures 9 and 10.

5. Four-Channel Operation —Twinmode

An extension of the Twinplex system has been carried out to provide 4-channel operation on a radio transmitter equipped with a high-level amplitude modulator. This system, called Twinmode, utilizes two groups of Twinplex keying, one group on the carrier-shift side to provide channels *A* and *B* and the second group on a frequency-shifted subcarrier applied through an amplitude modulator to provide channels *C* and *D*. Standard Twinplex equipment already described is used with one additional unit, an audio-shift keyer, being required to translate

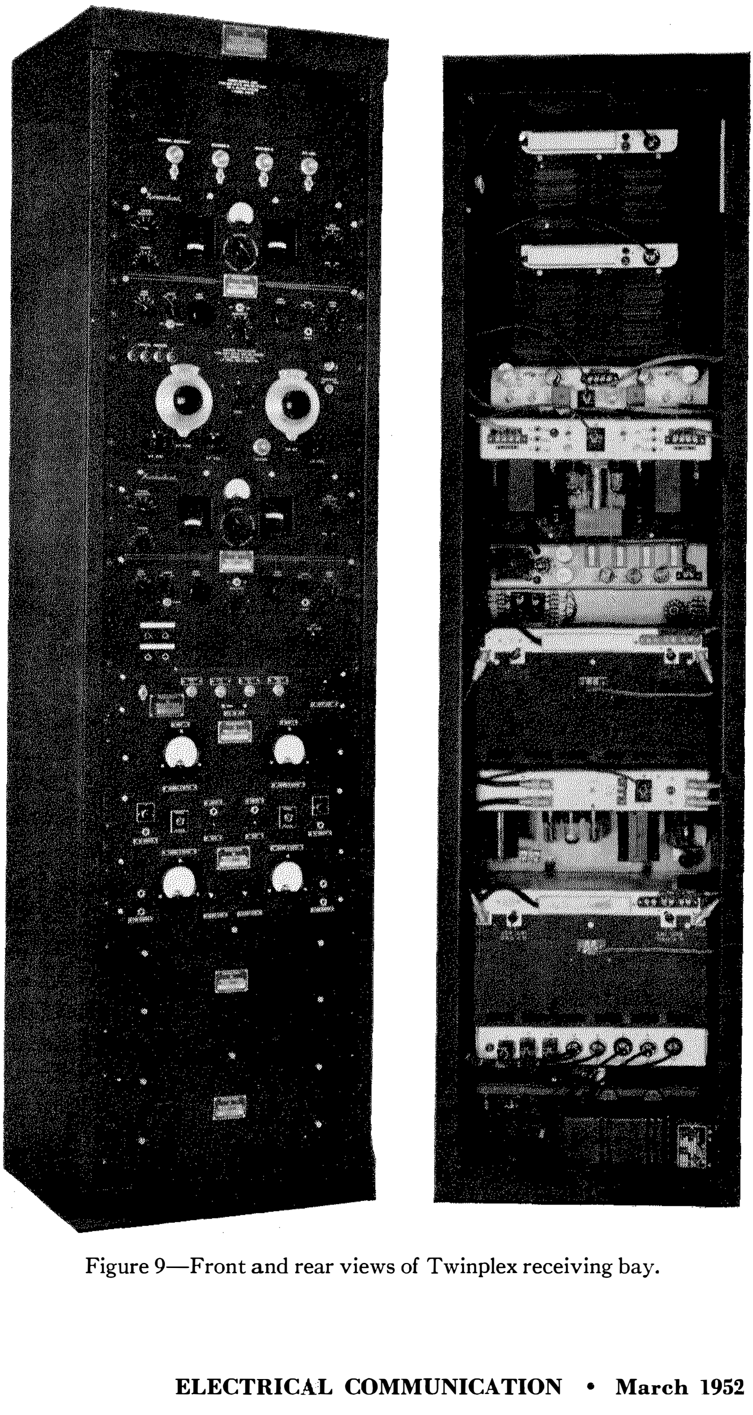


Figure 9—Front and rear views of Twinplex receiving bay.

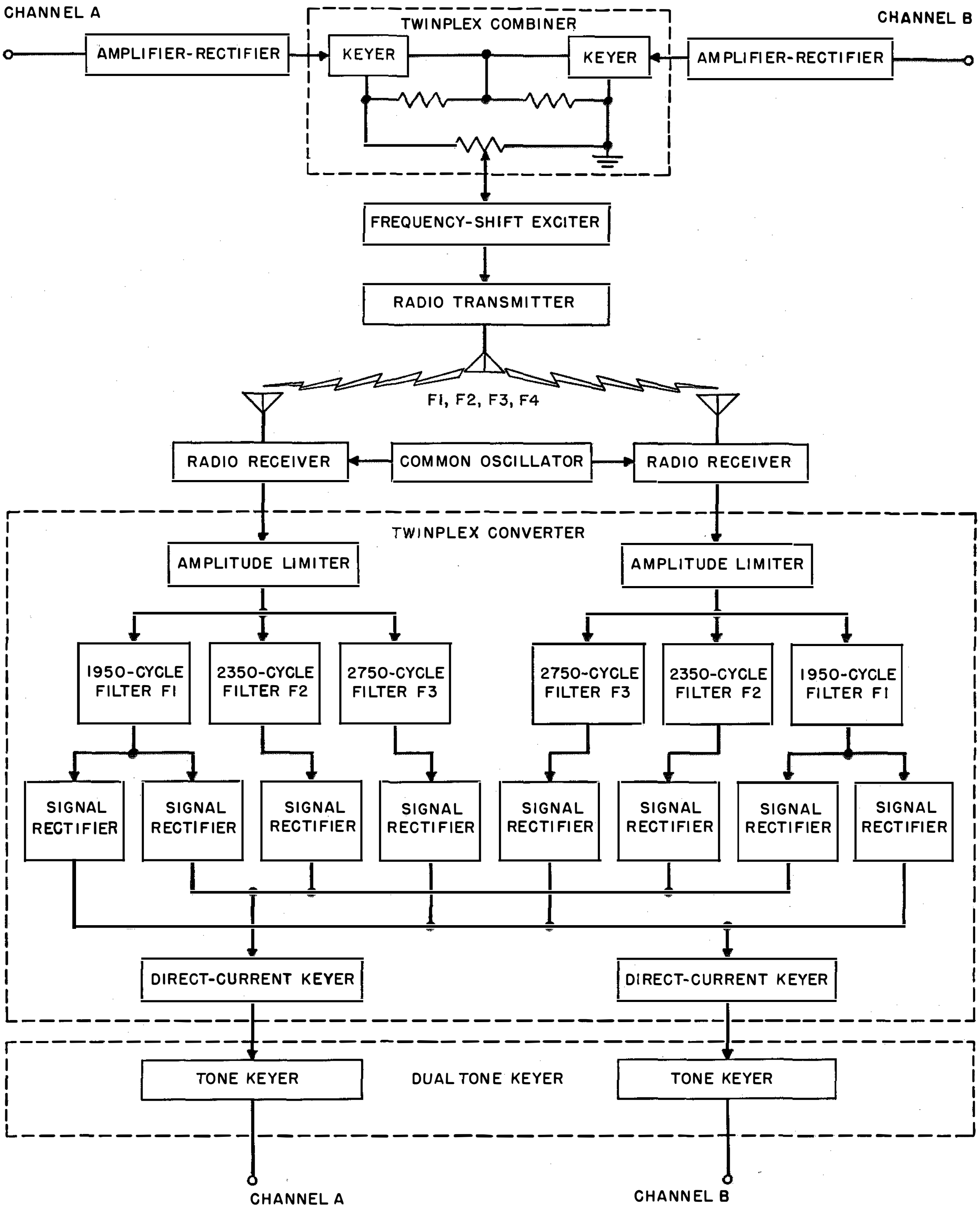


Figure 10—Block diagram of a dual-diversity Twinplex system. The keying voltages and frequencies are given in Table 2.

the combiner direct-current output pulses into any one of 4 audio frequencies for keying on the subcarrier side. The 4 audio frequencies used to modulate the carrier are the same as those normally derived from a Twinplex receiver by beat-frequency detection for carrier-shift reception, namely, 1950, 2350, 2750, and 3150 cycles.

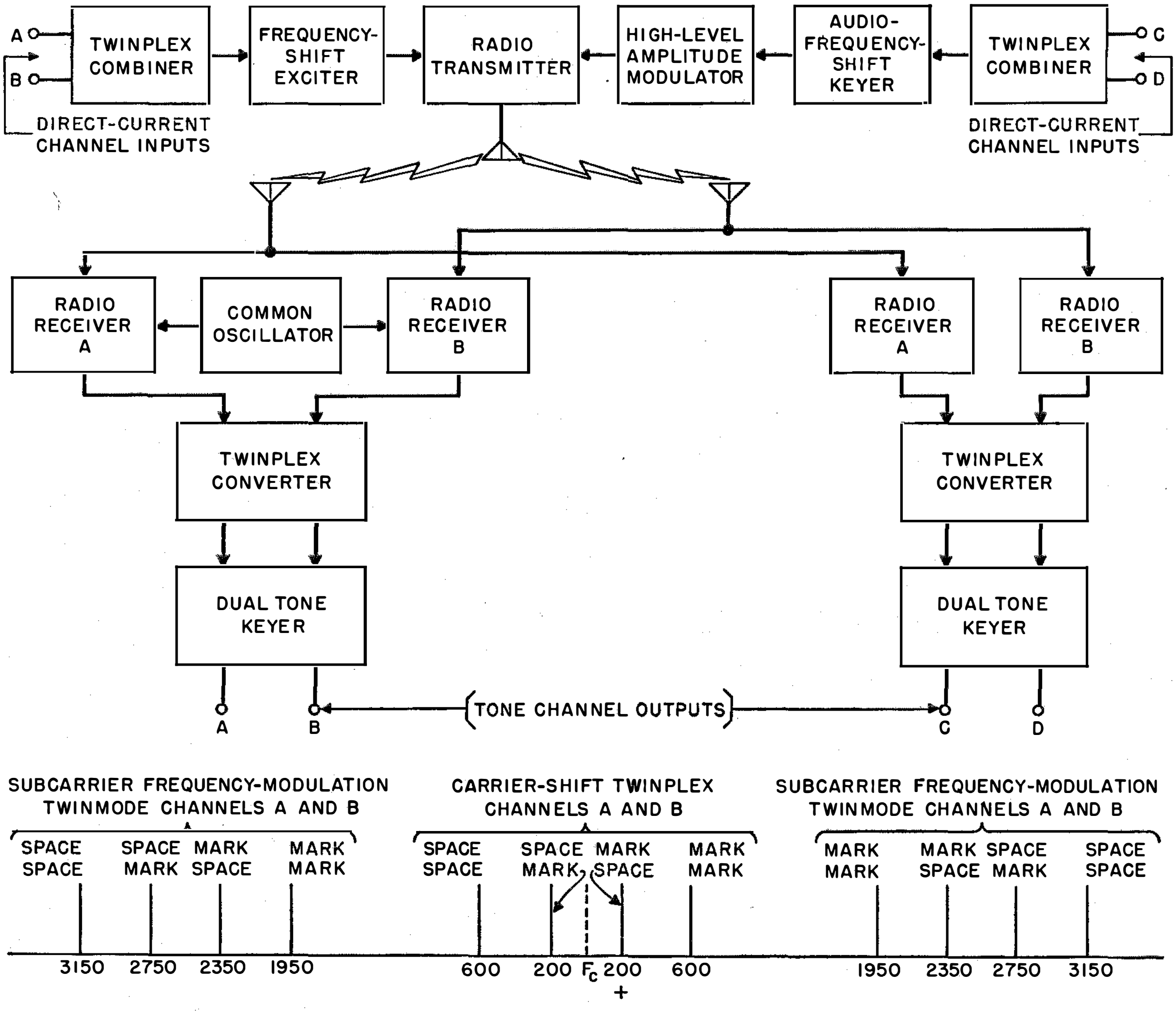


Figure 11—Block diagram of Twinmode system. The signaling frequencies in cycles relative to the transmitted center frequency F_c are indicated for a radio channel 7500 cycles wide.

This permits the conversion equipment for the subcarrier frequency-modulated channels to be identical with that already described for receiving two channels on the carrier-shift side. The only difference in reception technique is that the subcarrier frequency-modulated channels, *C* and *D*, are received with the beating intermediate-frequency oscillator turned off. Figure 11 shows a Twinmode radio circuit.

The audio-shift keyer designed for use with this system consists of two stable oscillators operating near 150 kilocycles, which are adjusted so that the frequency difference between them produces the required audio frequency at the output of a mixer stage. The frequency of one of the oscillators is shifted by means of a reactance-tube modulator, whose grid is biased by the direct-current keying pulses from a Twinplex combiner unit. The mixer stage is followed by a cathode-follower output tube and then a 1500-to-3500-cycle bandpass filter to remove any existing distortion in the signal. For a linear frequency shift of 1200 cycles, from 1950 to 3150 cycles, the attendant amplitude change in output level is less than 5 percent. This unit delivers about reference power (6 milliwatts into 600 ohms) and may be connected directly to the speech-amplifier input of the modulated radio transmitter. Panel space required is $5\frac{1}{4}$ inches. Figure 12 shows the audio-shift keyer.

The transmitter is adjusted to 80-percent amplitude modulation for Twinmode operation. Full modulator power is always concentrated in one pair of prime side frequencies plus some keying sidebands. This gives about a 3-decibel improvement over the use of a pair of mark and space tones for each channel on the frequency-modulated subcarrier. Total bandwidth for four channels keying, two on carrier shift, and two on subcarrier frequency modulation is about 8 kilocycles with double-sideband modulation. With the audio modulating frequencies chosen, there is no direct interference caused by the *C* and *D* channels on subcarrier frequency modulation to the *A* and *B* channels on carrier shift, or vice versa. A compilation of the possible carrier beat frequencies shows that the nearest interfering tones at the receiver output will be 1200 cycles, on the low side, and 3900 cycles, on the high side, of the converter input bandpass filter. At 1200 cycles, the level is 50 decibels down and at 3900 cycles it is 40 decibels down from the passband level.

Under multipath propagation conditions, however, the differences in successive mark and space carrier signal amplitudes may be very great. These variations in carrier mark and space levels may cause clicks to be produced in the output of the linear diode detector used for receiving the subcarrier frequency-modulation channels. The clicks have a high harmonic content and can, under certain propagation conditions, cause mutilation of the *C* and *D* channels. It has been found that high-pass filtering immediately after the diode detector is beneficial in reducing these harmful effects. A 1400-cycle high-pass filter having a steep attenuation characteristic has been used with good results for suppressing the click fundamental and all harmonics up to the desired pass-band region starting at 1500 cycles. Channels *C* and *D* suffer a power disadvantage of around 4 decibels compared to the carrier-shift channels, *A* and *B*. Also, the receiver intermediate-frequency bandwidth acceptance must be 8 kilocycles as compared to 3 kilocycles required for the carrier-shift side, thereby further decreasing the signal-to-noise ratio of the received subcarrier frequency-modulation signal. Repeated observations show that due to the above deficiencies the subcarrier frequency-modulation channels will fail somewhat earlier, on a normal propagation day compared to the carrier-shift channels. During transitional periods, two-channel operation may, therefore, be employed. The two carrier-shift channels are not degraded by the presence of the subcarrier frequency modulation at any time.

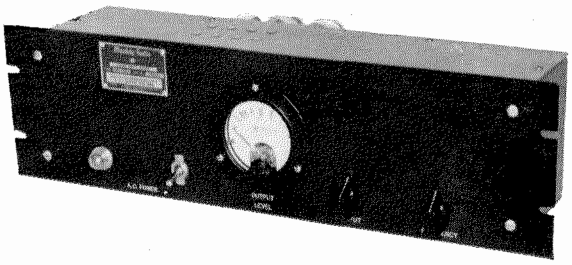


Figure 12—Audio-shift keyer.

The Twinmode system has been tested over a 3500-mile path with satisfactory results on 8-, 13-, and 19-megacycle frequencies with transmitter carrier power inputs of 5 to 12 kilowatts. The flexibility of channel usage and simplicity of operation, as well as the standardization of equipment used, make this system attractive for use in mixed-code communications where more than the two channels provided by Twinplex carrier-shift operation are required.

More recently the New York-to-Lima, Peru, radio circuit shown in Figure 13 was changed over from Twinplex to Twinmode operation. The Twinplex circuit formerly carried a 3-element cable-code channel, which was used at Lima to key the cable chain running down the west coast of South America to Valparaiso, across the Andes to Buenos Aires, and up the east coast to Rio de Janeiro. The Twinmode circuit now in operation provides this same cable-code channel on the subcarrier transmission, occupying channels *C* and *D*. At the same time, two 60-word-per-minute printer circuits are provided on channels *A* and *B*. The *A* printer channel is also taken off at Lima and forwarded to a customer's office on a leased basis. The New York Twinmode transmissions will also be received at Bogota, Colombia, where the *B*-channel signals will be selected to operate a printer, thereby releasing the two assigned carrier frequencies, two antennas, and the transmitter formerly used to provide this service on a straight single-channel frequency-shift basis. To accomplish this, it is only necessary to provide Bogota with a Twinplex converter unit to replace a single-channel frequency-shift converter.

The commercial operation of a circuit of the type just described clearly demonstrates the advantages of versatility and flexibility that accrue through the use of a system employing frequency-division principles.

6. Future Developments

Frequency-shift transmission is basically single-sideband technique as applied to telegraphy wherein the intermediate-frequency beat oscillator in the receiver acts as the reinserted carrier and the information is conveyed by the beat tones between this local carrier and the mark and space sidebands that are transmitted. When multichannel telegraphy on a single-sideband basis is practiced, it is customary to use the same type of transmitter and receiver as is required for telephony—with the exception that pairs of mark–space tones are substituted for voice or program modulation and the necessary filters for their separation are applied at the receiving end. It is suggested that a single-sideband system designed specifically for telegraph service would result in equipment of considerably less circuit complexity and cost while at the same time providing increased effectiveness and flexibility in circuit operations. This type of system may be built up from existing frequency-shift and Twinplex techniques. A proposed single-sideband telegraph system having this general form and using certain equipment already described as building blocks will be briefly described.

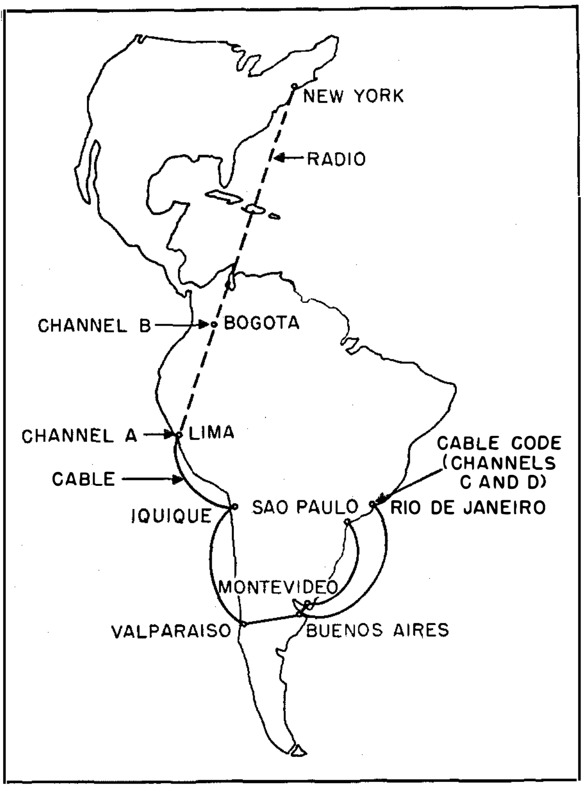


Figure 13—A Twinmode radio circuit from New York to Lima also keys on a subcarrier channel the cable system that extends to Rio de Janeiro. Bogota is served as well by one of the Twinmode channels.

The single-sideband exciter at the transmitting end would consist of four stable low-distortion frequency-shifted oscillators symmetrically spaced around 200 kilocycles. A reactance modulator is associated with each oscillator and is keyed from a standard Twinplex combiner unit, described in Section 3, thus providing four 2-channel groups for a total of 8 channels. The oscillator outputs are combined and applied to a fixed balanced modulator from which the high-frequency sidebands produced by a 1.8-megacycle crystal and the 200-kilocycle oscillator frequencies are taken off. The four groups of shifted 2-megacycle frequencies are applied to a second balanced modulator and are mixed with 6-to-26-megacycle frequencies from a crystal oscillator and multiplier chain to produce low-frequency sidebands in the 4-to-24-megacycle range. This is followed by a straight linear amplifier to provide a single-sideband output of several watts suitable, after passing through a coaxial line, for driving the next stage in the transmitter. Alternatively, it may be desirable to make the exciter part of the transmitter proper.

Certain types of transmitters now employed

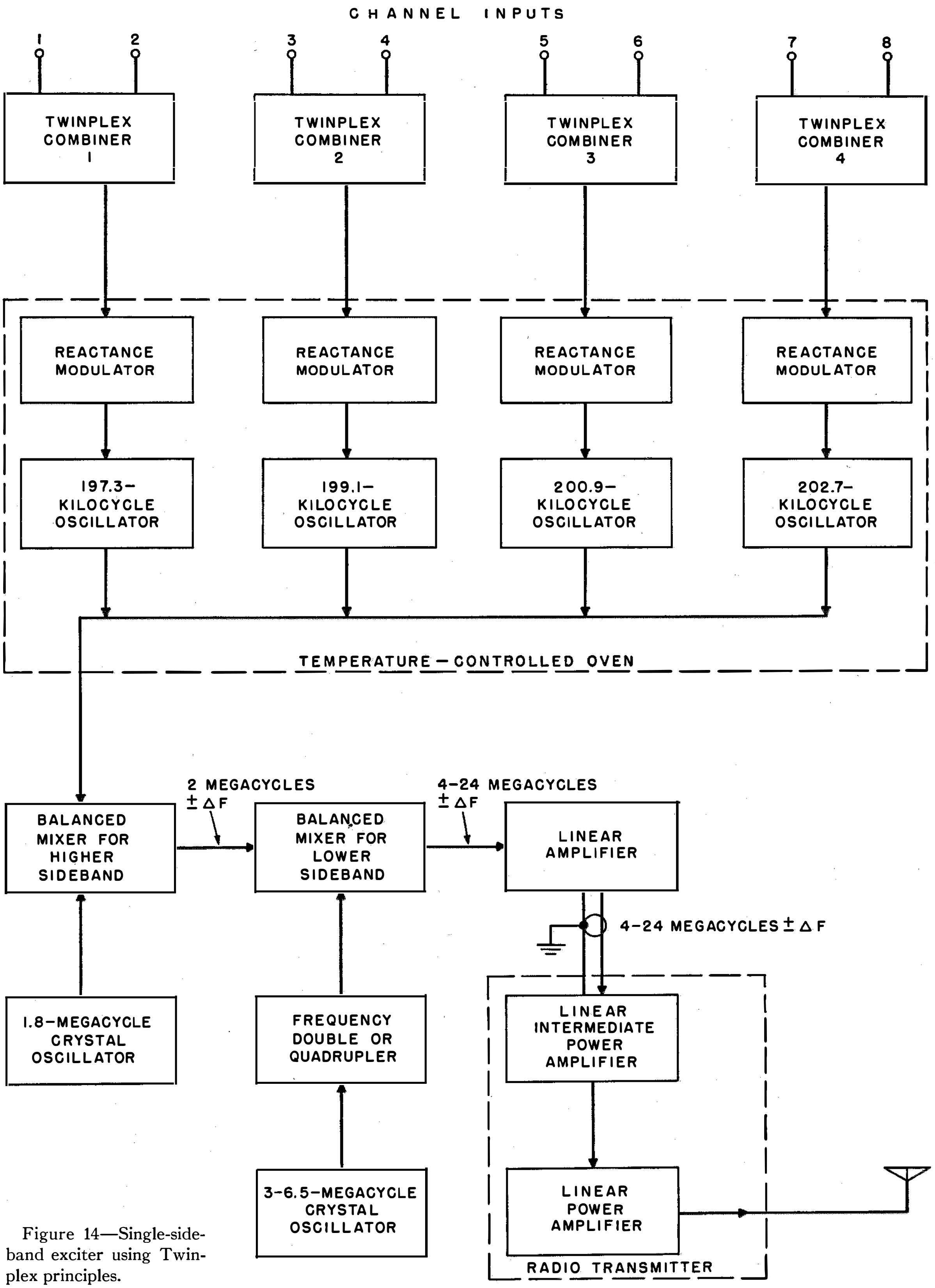


Figure 14—Single-sideband exciter using Twinplex principles.

for telegraphy using class-*C* amplifiers may be suitably modified for linear operation of the intermediate and power amplifiers so they may be driven with several watts from the single-sideband exciter output. There is, of course, a specific problem with each different transmitter. One type of transmitter presently operated in class-*C* uses two *4-250A* tubes in parallel in the intermediate power amplifier and an *880* in the power amplifier. The problem of operating these two stages as linear class-*B* amplifiers does not appear difficult. A functional block diagram of the proposed single-sideband telegraph exciter is shown in Figure 14. By utilizing the Twinplex combination scheme, only four shifted oscillators are required as compared to eight for conventional multitone practice. This results in an over-all power gain of 3 decibels since the available power output is distributed among half the number of frequencies at any time. Also, the intermodulation possibilities are reduced.

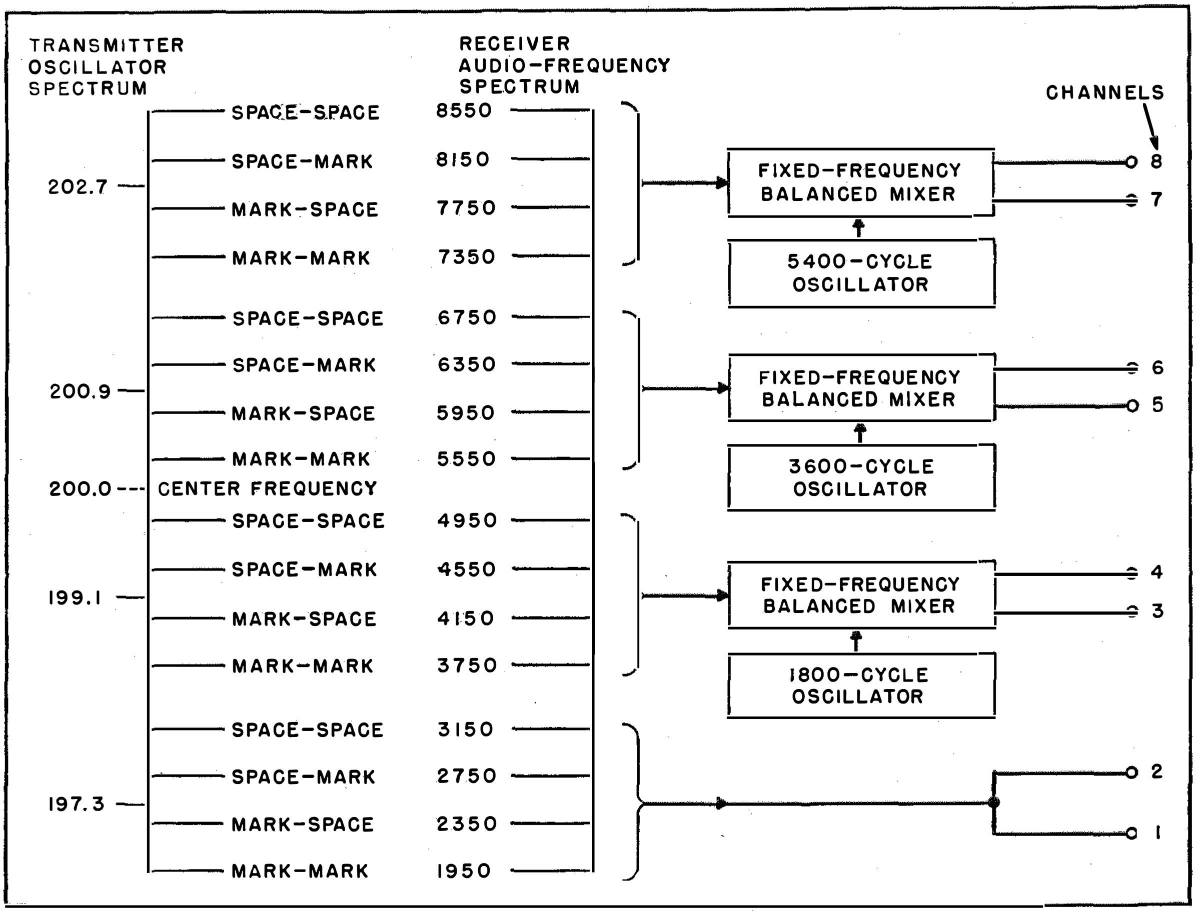


Figure 15—Single-sideband signaling frequencies. There are four groups of four frequencies each. The spacing between groups is 600 cycles and between adjacent frequencies in a group, 400 cycles, making a total spectrum of 6600 cycles. The center frequency of the oscillator is 200 kilocycles, which is multiplied to the assigned transmission frequency from which the receiver audio-frequency spectrum is recovered. A 470.25-kilocycle oscillator beats against the 465-kilocycle intermediate frequency to produce the above spectrum.

A standard dual-diversity Twinplex receiving bay of the type already described and shown in Figure 9 would form the basis of reception. For 8 channels, three additional Twinplex conversion equipments will be required. These are the standard units illustrated in Figure 6 and now used for 2-channel operation. In order to utilize the same filter frequencies in all converters, thereby effecting a valuable standardization in manufacture, the receiver audio frequencies produced by the single-sideband transmission, extending to 8550 cycles, will be changed to the basic four filter frequencies in each case, namely 1950, 2350, 2750, and 3150 cycles. This may be done quite simply by means of a fixed oscillator and mixer stage in front of each standard converter input. Figure 15 shows the actual frequency situation that would exist at the transmitter and at the output of the receiver.

The system described herein is highly compatible with certain existing single- and two-channel frequency-shift equipments thereby minimizing obsolescence when channel requirements increase on a given radio circuit. True single-sideband telegraphy results, with a 3-decibel power gain over conventional mark–space tone keying of each channel. A new multichannel radiotelegraph system utilizing these principles is now being developed for commercial use.

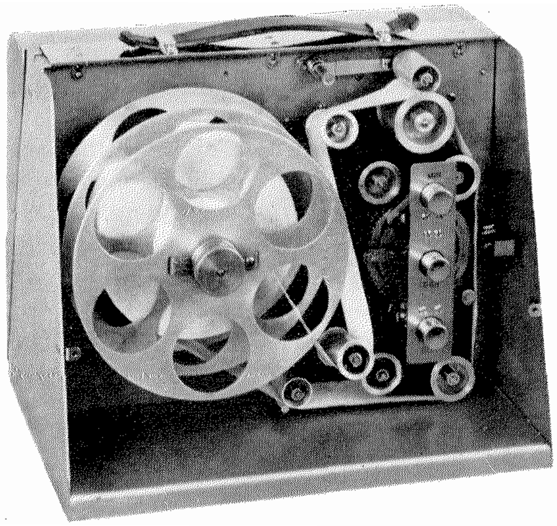
Recent Telecommunication Development

Printing Register

SUBSCRIBER-LINE activities, malicious calls, and toll calls in automatic telephone systems may be recorded on paper tape with a printing register designed by Bell Telephone Manufacturing Company.

The equipment is mounted in a self-contained unit of either portable or fixed form and can be connected to the exchange apparatus by jacks or patch cords.

Five printing wheels are actuated by electromagnetic clutches and for subscriber-line observations may record the date, hour, and minute of start and termination of each call, the number of the called line, and a metering indication. As many as 99 different tariffs or other metering data may be indicated.



Modifications may be made to adapt the register for observation on toll junctions in systems using ticket printers. Three of the printing wheels record time in hours, minutes, and seconds. The fourth wheel records toll prefix, selection pulses, called number, calling number, tariff, and release of connection. The fifth wheel provides for start, translation of selection, end of selection, answer of called subscriber, and end of connection. The last two wheels indicate 20 and 10 numbers, respectively. This record is very complete and covers all phases of the establishment and release of a connection.

A master clock provides the required signals for controlling the time wheels.