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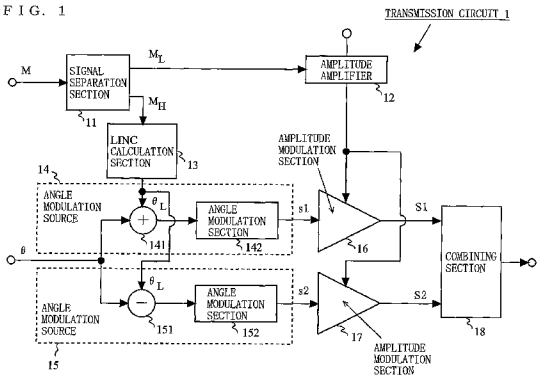
(54) **Title:** LINC TRANSMISSION CIRCUIT AND COMMUNICATION DEVICE USING THE SAME

FIG. 1



(57) **Abstract:** Provided is a transmission circuit which is: capable of outputting a highly linear transmission signal regardless of a bandwidth; small in size; and capable of operating with high efficiency. A signal separation section (11) separates an amplitude signal into a high frequency amplitude signal and a low frequency amplitude signal. An amplitude amplifier (12) supplies amplitude modulation sections (16, 17) with a voltage controlled in accordance with the low frequency amplitude signal. A LINC calculation section (13) outputs, based on a calculation using the high frequency amplitude signal, a calculation phase signal. Angle modulation sources (14, 15) respectively angle-modulate signals which result from adding/subtracting the calculation phase signal to/from a phase signal, and respectively output a first angle-modulated signal and a second angle-modulated signal. The amplitude modulation sections (16, 17) respectively amplitude-modulate the first angle-modulated signal and the second angle-modulated signal, and respectively output a first modulation signal and a second modulation signal. A combining section (18) combines the first modulation signal and the second modulation signal, thereby generating the transmission signal.

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DESCRIPTION

LINC TRANSMISSION CIRCUIT AND COMMUNICATION DEVICE USING THE SAME

TECHNICAL FIELD

[0001] The present invention relates to a transmission circuit used in communication devices such as mobile phones and wireless LAN devices. The present invention particularly relates to a transmission circuit which is: capable of outputting a highly linear transmission signal regardless of a bandwidth; small in size; and capable of operating with high efficiency, and to a communication device using the transmission circuit.

BACKGROUND ART

[0002] Communication devices such as mobile phones and wireless LAN devices are required to, whether operating over a wide bandwidth or a narrow bandwidth, secure linearity of a transmission signal and operate with low power consumption. A transmission circuit used in such communication devices is: capable of outputting a highly linear transmission signal regardless of a bandwidth; small in size; and capable of operating with high efficiency. Hereinafter, such conventional transmission circuits will be described.

[0003] One of such conventional transmission circuits is, for example, a transmission circuit which uses a modulation method such as a quadrature modulation method to generate a transmission

signal (hereinafter, referred to as a quadrature modulation circuit). Since the quadrature modulation circuit is well known, a description thereof will be omitted. A conventional transmission circuit, which is able to output a highly linear transmission signal and operate more efficiently than the quadrature modulation circuit, is, e.g., a transmission circuit 500 shown in FIG. 20. FIG. 20 is a block diagram showing a configuration of the conventional transmission circuit 500. As shown in FIG. 20, the conventional transmission circuit 500 comprises a signal generation section 501, an angle modulation section 502, an amplitude amplifier 503, an amplitude modulation section 504 and an output terminal 505.

[0004] In the conventional transmission circuit 500, the signal generation section 501 generates an amplitude signal and a phase signal. The amplitude signal is inputted to the amplitude amplifier 503. The amplitude amplifier 503 supplies a voltage to the amplitude modulation section 504 in accordance with the inputted amplitude signal. The phase signal is inputted to the angle modulation section 502. The angle modulation section 502 angle-modulates the inputted phase signal, and outputs an angle-modulated signal. The angle-modulated signal outputted from the angle modulation section 502 is inputted to the amplitude modulation section 504. The amplitude modulation section 504 amplitude-modulates the angle-modulated signal by using the voltage supplied from the amplitude amplifier 503, and outputs

a resultant signal as a modulation signal. The modulation signal is outputted from the output terminal 505 as a transmission signal. Note that, the transmission circuit 500 as described above is referred to as a polar modulation circuit.

[0005] Another conventional transmission circuit, which is able to output a highly linear transmission signal and operate more efficiently than the quadrature modulation circuit, is, e.g., a transmission circuit 600 shown in FIG. 21 which is referred to as LINC (Linear Amplification using Nonlinear Components). FIG. 21 is a block diagram showing a configuration of the conventional transmission circuit 600. As shown in FIG. 21, the conventional transmission circuit 600 comprises a constant amplitude signal generation circuit 601, an amplifier 602, an amplifier 603 and a combining circuit 604.

[0006] The constant amplitude signal generation circuit 601 outputs, based on an input signal, two modulation signals which are different in phase and each of which has a constant amplitude (hereinafter, referred to as constant amplitude signals). The two constant amplitude signals outputted from the constant amplitude signal generation circuit 601 are amplified by the amplifiers 602 and 603, respectively, and then inputted to the combining circuit 604. The combining circuit 604 combines an output signal S1 of the amplifier 602 and an output signal S2 of the amplifier 603, and outputs the combined signal as a transmission signal S0.

[0007] Here, the transmission signal S0, the output signal S1 of the amplifier 602, and the output signal S2 of the amplifier 603 can be represented using equations (1) to (4). In the equations (1) to (4), m(t) represents an amplitude component of the transmission signal S0; θ (t) represents a phase component of the transmission signal S0; Mx represents a magnitude of an amplitude of the output signal S1 of the amplifier 602 and a magnitude of an amplitude of the output signal S2 of the amplifier 603; and ϕ (t) represents a phase shift of each of the output signals S1 and S2 with respect to the transmission signal S0.

$$S0(t) = m(t)\exp[j\theta(t)] = S1(t) + S2(t) \quad \cdots \text{[equation 1]}$$

$$S1(t) = Mx\exp[j\{\theta(t) + \phi(t)\}] \quad \cdots \text{[equation 2]}$$

$$S2(t) = Mx\exp[j\{\theta(t) - \phi(t)\}] \quad \cdots \text{[equation 3]}$$

$$\phi(t) = \cos^{-1}\left[\frac{m(t)}{2Mx}\right] \quad \cdots \text{[equation 4]}$$

[0008] FIG. 22 is a diagram for describing in detail operations performed by the conventional transmission circuit 600. As shown in FIG. 22, the conventional transmission circuit 600 reduces the phase shift of each of the output signals S1 and S2 with respect to the transmission signal S0, thereby outputting the transmission signal S0 which is great in magnitude (see FIG. 22(a)). Also, the transmission circuit 600 enlarges the phase shift of each of the output signals S1 and S2 with respect to the transmission signal S0, thereby outputting the transmission signal S0 which is small in magnitude (see FIG. 22(b)). In other words, the transmission

circuit 600 can control the magnitude of the transmission signal S0, by controlling the phase shift of each of the two constant amplitude signals outputted from the constant amplitude signal generation circuit 601.

[0009] However, since the conventional transmission circuit 600 generates the transmission signal S0 by combining, e.g., the output signals S1 and S2, there is a problem that when phase errors or amplitude errors are contained in the output signals S1 and S2, it is difficult to realize a desired transmission signal S0.

[0010] There is a disclosed conventional transmission circuit called LINC which is capable of correcting the phase error or amplitude error contained in the output signals S1 and S2 (e.g., Patent Document 1). FIG. 23 is a block diagram showing a configuration of a conventional transmission circuit 700 disclosed in Patent Document 1. As shown in FIG. 23, the conventional transmission circuit 700 comprises the constant amplitude signal generation circuit 601, the amplifiers 602 and 603, the combining circuit 604, a phase detector 701, a variable phase shifter 702, an amplitude difference detector 703 and a variable attenuator 704.

[0011] In the conventional transmission circuit 700, the phase detector 701 detects a phase error contained in the output signal S1 of the amplifier 602. The variable phase shifter 702 corrects, based on the detected phase error, a phase of a constant amplitude signal generated by the constant amplitude signal generation

circuit 601. The amplitude difference detector 703 detects an amplitude error contained in the output signal S2 of the amplifier 603. The variable attenuator 704 corrects, based on the detected amplitude error, an amplitude of the constant amplitude signal generated by the constant amplitude signal generation circuit 601. This allows the conventional transmission circuit 700 to realize a desired transmission signal S0.

[Patent Document 1] Japanese Laid-Open Patent Publication No. 5-37263

DISCLOSURE OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0012] However, the conventional transmission circuit 500 (see FIG. 20) has a problem that it is difficult, when operating over a wide band, to secure a band for the amplitude amplifier 503 and to enable the amplitude amplifier 503 to operate with high efficiency. For example, the conventional transmission circuit 500 is able to allow the amplitude amplifier 503 to operate with high efficiency in the case where a switching regulator is used for the amplitude amplifier 503. In this case, however, it is difficult to, when operating over a wide band, to secure a band for the switching regulator. For this reason, the conventional transmission circuit 500 is not always able to operate with high efficiency.

[0013] Also, the conventional transmission circuit 600 (see

FIG. 21) has, as described above, the problem that since the circuit 600 generates the transmission signal S0 by combining the output signals S1 and S2 having different phases, it is difficult to realize a desired transmission signal S0 due to phase errors or amplitude errors contained in the transmission signals S1 and S2. Also, in the conventional transmission circuit 600, there is a possibility that a significant combining loss occurs when the output signals S1 and S2 are combined. Accordingly, the conventional transmission circuit 600 is not always able to operate with high efficiency.

[0014] Further, the conventional transmission circuit 700 (see FIG. 23) has a problem that there is a necessity to have a large number of components in order to correct the phase errors or amplitude errors contained in the output signals S1 and S2 (e.g., the phase detector 701, the variable phase shifter 702, the amplitude difference detector 703 and the variable attenuator 704), and this causes an increase in size of the circuit. Also, in the conventional transmission circuit 700, a loss occurs since an output of each of the amplifiers 602 and 603 is branched, and this causes power consumption of the transmission circuit 700 to be greater than that of the transmission circuit 600.

[0015] Therefore, an object of the present invention is to provide a transmission circuit which is small in size and capable of, even in the case of a wideband signal, operating with high efficiency and outputting a highly linear transmission signal,

and to provide a communication device using the transmission circuit.

SOLUTION TO THE PROBLEMS

[0016] The present invention is directed to a transmission circuit for generating a transmission signal based on an input amplitude signal and an input phase signal, and outputting the transmission signal. In order to achieve the above object, the transmission circuit of the present invention comprises: a signal separation section for separating the input amplitude signal into a high-frequency amplitude signal and a low-frequency amplitude signal; an amplitude amplifier for outputting a signal controlled in accordance with the low-frequency amplitude signal; a LINC calculation section for outputting, based on a predetermined calculation using the high-frequency amplitude signal, a calculation phase signal whose phase changes in accordance with the high-frequency amplitude signal; a first angle modulation source for generating a first angle-modulated signal by angle-modulating the input phase signal and the calculation phase signal in such a manner that the calculation phase signal is added to the input phase signal; a second angle modulation source for generating a second angle-modulated signal by angle-modulating the input phase signal and the calculation phase signal in such a manner that the calculation phase signal is subtracted from the input phase signal; a first amplitude modulation section for

amplitude-modulating the first angle-modulated signal by using the signal outputted from the amplitude amplifier, and outputting a resultant signal as a first modulation signal; a second amplitude modulation section for amplitude-modulating the second angle-modulated signal by using the signal outputted from the amplitude amplifier, and outputting a resultant signal as a second modulation signal; and a combining section for combining the first modulation signal and the second modulation signal, and outputting a resultant signal as the transmission signal. The LINC calculation section outputs, as the calculation phase signal, arccosine of a value obtained by dividing the high-frequency amplitude signal by a constant value.

[0017] Preferably, the signal separation section extracts, from the input amplitude signal, a lower frequency component than a predetermined frequency, and outputs the extracted component as the low-frequency amplitude signal, and outputs the high-frequency amplitude signal which results from dividing the input amplitude signal by the low-frequency amplitude signal.

[0018] The signal separation section may include: a low-pass filter for extracting, from the input amplitude signal, a lower frequency component than a predetermined frequency, and outputting the extracted component as the low-frequency amplitude signal; and a dividing section for outputting the high-frequency amplitude signal which results from dividing the input amplitude signal by the low-frequency amplitude signal.

[0019] Preferably, the first angle modulation source includes: an addition section for outputting a signal resulting from adding the calculation phase signal to the input phase signal; and a first angle modulation section for angle-modulating the signal outputted from the addition section, and outputting a resultant signal as the first angle-modulated signal. The second angle modulation source includes: a subtraction section for outputting a signal resulting from subtracting the calculation phase signal from the input phase signal; and a second angle modulation section for angle-modulating the signal outputted from the subtraction section, and outputting a resultant signal as the second angle-modulated signal.

[0020] The first angle modulation source may include: a first angle modulation section for angle-modulating the input phase signal; and a second angle modulation section for angle-modulating a signal, which has been angle-modulated by the first angle modulation section, in such a manner that the calculation phase signal is added to the signal, and outputting a resultant signal as the first angle-modulated signal. The second angle modulation source may include: a third angle modulation section for angle-modulating the input phase signal; and a fourth angle modulation section for angle-modulating a signal, which has been angle-modulated by the third angle modulation section, in such a manner that the calculation phase signal is subtracted from the signal, and outputting a resultant signal as the second

angle-modulated signal.

[0021] Preferably, the amplitude amplifier is structured by a switching regulator, and supplies each of the first and second amplitude modulation sections with a voltage which is controlled in accordance with the low-frequency amplitude signal. Alternatively, the amplitude amplifier may be structured by a series regulator, and may supply each of the first and second amplitude modulation sections with a voltage which is controlled in accordance with the low-frequency amplitude signal.

[0022] Preferably, the transmission circuit further comprises a multiplying section for multiplying the low-frequency amplitude signal by power information inputted from a baseband, which multiplying section is positioned between the signal separation section and the amplitude amplifier.

[0023] The amplitude amplifier may have a configuration in which a switching regulator and a series regulator are serially connected. In this case: the switching regulator supplies the series regulator with a voltage which is controlled in accordance with the power information inputted from the baseband; and to each of the first and second modulation sections, the series regulator supplies, as a bias voltage, the voltage supplied from the switching regulator, and also supplies a voltage which is controlled in accordance with an output signal of the multiplying section.

[0024] The transmission circuit may further comprise a distortion compensation section for compensating for AM-PM

distortion or AM-AM distortion which occurs in at least either one of the amplitude amplifier, the first amplitude modulation section and the second amplitude modulation section.

[0025] The present invention is also directed to a communication device comprising the above-described transmission circuit. The communication device comprises: a transmission circuit for generating a transmission signal; and an antenna for outputting the transmission signal generated by the transmission circuit. The communication device may further comprise: a reception circuit for processing a reception signal received from the antenna; and an antenna duplexer for outputting the transmission signal generated by the transmission circuit to the antenna, and outputting the reception signal received from the antenna to the reception circuit.

EFFECT OF THE INVENTION

[0026] As described above, according to the present invention, the low frequency amplitude signal, i.e., a lower frequency component than a predetermined frequency which is extracted from the amplitude signal, is inputted to the amplitude amplifier. As a result, the transmission circuit is able to, even when operating over a wide band, secure a band for the amplitude amplifier and allow the amplitude amplifier to operate with high efficiency. Further, since the LINC calculation section outputs the calculation phase signal by performing a calculation using the high frequency

amplitude signal whose envelope variation is small. Therefore, an angle of the calculation phase signal is small and an angle change thereof is also small. For this reason, a phase difference between the first modulation signal and the second modulation signal is small. Consequently, when the first modulation signal and the second modulation signal are combined, deterioration of a transmission signal, which is caused by an amplitude error or phase error, and a combining loss can be reduced. Still further, since an envelope of each of the first angle-modulated signal and the second angle-modulated signal is constant, non-linear amplitude modulation sections can also be used. This allows the transmission circuit to: be small in size; operate with high efficiency; and output a highly linear transmission signal regardless of a bandwidth.

[0027] Still further, by using the above-described transmission circuit, the communication device of the present invention is able to: secure a precision of an output signal over a wide bandwidth; be small in size; and operate with high efficiency.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028] [FIG. 1] FIG. 1 is a block diagram showing an exemplary configuration of a transmission circuit 1 according to a first embodiment of the present invention.

[FIG. 2] FIG. 2 shows an exemplary waveform of a high frequency amplitude signal M_H.

[FIG. 3] FIG. 3 shows relationships among the high frequency amplitude signal M_H, a calculation phase signal θ_L and a constant value M_0.

[FIG. 4A] FIG. 4A shows an exemplary spectrum of a transmission signal which is outputted from the transmission circuit 1 in the case of using EDGE technology.

[FIG. 4B] FIG. 4B shows an exemplary spectrum of an amplitude signal M inputted to a signal separation section 11.

[FIG. 5] FIG. 5 is a block diagram showing in detail an exemplary configuration of the signal separation section 11.

[FIG. 6A] FIG. 6A is a block diagram showing in detail an exemplary configuration of a series regulator 12a.

[FIG. 6B] FIG. 6B is a block diagram showing in detail an exemplary configuration of a switching regulator 12b.

[FIG. 6C] FIG. 6C is a block diagram showing in detail an exemplary configuration of a current-driven regulator 12c.

[FIG. 7A] FIG. 7A is a block diagram showing in detail an exemplary configuration of an amplitude modulation section 16a.

[FIG. 7B] FIG. 7B is a block diagram showing in detail an exemplary configuration of an amplitude modulation section 16b.

[FIG. 8] FIG. 8 is a block diagram showing an exemplary configuration of a transmission circuit 1a according to the first embodiment of the present invention.

[FIG. 9A] FIG. 9A is a block diagram showing an exemplary configuration of a transmission circuit 2 according to a second

embodiment of the present invention.

[FIG. 9B] FIG. 9B is a block diagram showing an exemplary configuration of a transmission circuit 2b according to the second embodiment of the present invention.

[FIG. 9C] FIG. 9C is a block diagram showing an exemplary configuration of a transmission circuit 2c according to the second embodiment of the present invention.

[FIG. 10] FIG. 10 is a block diagram showing in detail an exemplary configuration of an angle modulation source 24 according to the second embodiment of the present invention.

[FIG. 11] FIG. 11 is a block diagram showing an exemplary configuration of a transmission circuit 3 according to a third embodiment of the present invention.

[FIG. 12] FIG. 12 is a block diagram showing an exemplary configuration of a transmission circuit 3a according to the third embodiment of the present invention.

[FIG. 13] FIG. 13 is a block diagram showing an exemplary configuration of a transmission circuit 3b according to the third embodiment of the present invention.

[FIG. 14] FIG. 14 is a block diagram showing an exemplary configuration of a transmission circuit 4 according to a fourth embodiment of the present invention.

[FIG. 15] FIG. 15 shows an exemplary timing chart of signals used in the transmission circuit 4.

[FIG. 16] FIG. 16 is a block diagram showing an exemplary

configuration of a transmission circuit 1x according to the first embodiment which comprises a distortion compensation section 26.

[FIG. 17A] FIG. 17A is a block diagram showing an exemplary configuration of a transmission circuit 1y comprising BPFs 27 and 28.

[FIG. 17B] FIG. 17B is a block diagram showing an exemplary configuration of a transmission circuit 1z comprising a BPF 29.

[FIG. 17C] FIG. 17C is a block diagram showing in detail an exemplary configuration of a switching regulator 12d.

[FIG. 18A] FIG. 18A is a block diagram showing an exemplary configuration of a transmission circuit 3x comprising a current-driven amplitude amplifier 30.

[FIG. 18B] FIG. 18B is a block diagram showing an exemplary configuration of a transmission circuit 3y comprising the current-driven amplitude amplifier 30.

[FIG. 18C] FIG. 18C is a block diagram showing an exemplary configuration of a transmission circuit 4x comprising the current-driven amplitude amplifier 30.

[FIG. 19] FIG. 19 is a block diagram showing an exemplary configuration of a communication device according to a fifth embodiment of the present invention.

[FIG. 20] FIG. 20 is a block diagram showing a configuration of a conventional transmission circuit 500.

[FIG. 21] FIG. 21 is a block diagram showing a

configuration of a conventional transmission circuit 600.

[FIG. 22] FIG. 22 is a diagram for describing in detail operations performed by the conventional transmission circuit 600.

[FIG. 23] FIG. 23 is a block diagram showing a configuration of a conventional transmission circuit 700.

DESCRIPTION OF THE REFERENCE CHARACTERS

[0029]

1 to 3	transmission circuit
11	signal separation section
111	input terminal
112	low-pass filter
113	dividing section
114, 115	output terminal
12, 19, 22	amplitude amplifier
12a	series regulator
12b	switching regulator
12c	current-driven regulator
121	input terminal
122	comparing section
123	power source terminal
124, 130, 131	transistor
125	output terminal
126	signal conversion section
127	amplifying section
128	low-pass filter

129 variable power source
13 LINC calculation section
14, 15, 24, 25 angle modulation source
141 addition section
142, 241, 242, 251, 252 angle modulation section
2421 phase comparator
2422 low-pass filter
2423 voltage controlled oscillator
2424 frequency divider
151 subtraction section
152 angle modulation section
16, 17 amplitude modulation section
161, 165 input terminal
162, 168, 173 matching circuit
163, 166, 172, 174 bias circuit
164, 170 power source terminal
167, 171 transistor
169 output terminal
18 combining section
20 multiplying section
23 timing control section
26 distortion compensation section
27, 28, 29 BPF
30 current-driven amplitude amplifier
200 communication device

210 transmission circuit

220 reception circuit

230 antenna duplexer

240 antenna

BEST MODE FOR CARRYING OUT THE INVENTION

[0030] (first embodiment)

FIG. 1 is a block diagram showing an exemplary configuration of a transmission circuit 1 according to a first embodiment of the present invention. As shown in FIG. 1, the transmission circuit 1 comprises a signal separation section 11, an amplitude amplifier 12, a LINC calculation section 13, angle modulation sources 14 and 15, amplitude modulation sections 16 and 17, and a combining section 18. The angle modulation source 14 includes an addition section 141 and an angle modulation section 142. The angle modulation source 15 includes a subtraction section 151 and an angle modulation section 152. Hereinafter, operations performed by the transmission circuit 1 will be described with reference to FIG. 1.

[0031] As shown in FIG. 1, the signal separation section 11 separates an inputted amplitude signal M into a low frequency amplitude signal M_L and a high frequency amplitude signal M_H. To be specific, the signal separation section 11 extracts, from the amplitude signal M, a lower frequency component than a predetermined frequency, and outputs the extracted component as

a low frequency amplitude signal M_L, and also outputs a high frequency amplitude signal M_H which results from dividing the amplitude signal M by the low frequency amplitude signal M_L. At this point, a relationship shown in an equation (5) below is realized between the low frequency amplitude signal M_L and the high frequency amplitude signal M_H. FIG. 2 shows an exemplary waveform of the high frequency amplitude signal M_H. As shown in FIG. 2, in the waveform of the high frequency amplitude signal M_H, energy concentrates on a DC component. In other words, the high frequency amplitude signal M_H indicates a small envelope variation rate.

$$M_H(t) = \frac{M(t)}{M_L(t)} \quad \cdots \text{[equation 5]}$$

[0032] The low frequency amplitude signal M_L is inputted to the amplitude amplifier 12. The amplitude amplifier 12 supplies each of the amplitude modulation sections 16 and 17 with a signal controlled in accordance with the low frequency amplitude signal M_L. Typically, the amplitude amplifier 12 supplies each of the amplitude modulation sections 16 and 17 with a signal proportional to the low frequency amplitude signal M_L. Since the low frequency amplitude signal M_L, i.e., a lower frequency component than a predetermined frequency which is extracted from the amplitude signal M, is inputted to the amplitude amplifier 12, the transmission circuit 1 is able to, even when operating over a wide band, secure a band for the amplitude amplifier 12 and allow the amplitude amplifier 12 to operate with high efficiency.

[0033] On the other hand, the high frequency amplitude signal M_H is inputted to the LINC calculation section 13. The LINC calculation section 13 outputs, by performing a predetermined calculation using the high frequency amplitude signal M_H, a calculation phase signal θ_L whose phase changes in accordance with the high frequency amplitude signal M_H. To be specific, the LINC calculation section 13 performs the calculation using the high frequency amplitude signal M_H, thereby outputting the calculation phase signal θ_L as shown in an equation (6) below. Here, M_0 is a constant value, and a relationship as shown in an equation (7) below is realized between the high frequency amplitude signal M_H and the constant value M_0. That is, when the calculation phase signal $\theta_L = 0$, $2M_0 = |M_H|$. FIG. 3 shows relationships among the high frequency amplitude signal M_H, the calculation phase signal θ_L and the constant value M_0. As shown in FIG. 3, the variation ratio of the envelope of the high frequency amplitude signal M_H is small. Therefore, an angle of the calculation phase signal θ_L is small and an angle change thereof is also small.

$$\theta_L(t) = \cos^{-1}\left(\frac{M_H(t)}{2M_0}\right) \quad \cdots \text{[equation 6]}$$

$$2M_0 \le M_H \quad \cdots \text{[equation 7]}$$

[0034] The calculation phase signal θ_L outputted from the LINC calculation section 13 is inputted to each of the angle modulation sources 14 and 15. The angle modulation source 14 angle-modulates a phase signal θ and the calculation phase signal θ_L in such a

manner that the calculation phase signal θ_L is added to the phase signal θ, and outputs a resultant signal as a first angle-modulated signal s1. To be specific, in the angle modulation source 14, the addition section 141 adds the calculation phase signal θ_L to the phase signal θ, and then outputs a phase signal $\theta + \theta_L$. The angle modulation section 142 angle modulates the phase signal $\theta + \theta_L$ outputted from the addition section 141, and then outputs a resultant signal as the first angle-modulated signal s1.

[0035] The angle modulation source 15 angle-modulates the phase signal θ and the calculation phase signal θ_L in such a manner that the calculation phase signal θ_L is subtracted from the phase signal θ, and then outputs a resultant signal as a second angle-modulated signal s2. To be specific, in the angle modulation source 15, the subtraction section 151 subtracts the calculation phase signal θ_L from the phase signal θ, and then outputs a phase signal $\theta - \theta_L$. The angle modulation section 152 angle-modulates the phase signal $\theta - \theta_L$ outputted from the subtraction section 151, and then outputs a resultant signal as the second angle-modulated signal s2.

[0036] The first angle-modulated signal s1 is inputted to the amplitude modulation section 16. The amplitude modulation section 16 amplitude-modulates the first angle-modulated signal s1 in accordance with a signal supplied from the amplitude amplifier 12, and then outputs a resultant signal as a first modulation signal S1. The second angle-modulated signal s2 is inputted to the

amplitude modulation section 17. The amplitude modulation section 17 amplitude-modulates the second angle-modulated signal s2 in accordance with the signal supplied from the amplitude amplifier 12, and outputs a resultant signal as a second modulation signal S2. Note that, since an envelope of each of the first angle-modulated signal s1 and the second angle-modulated signal s2 is constant, the transmission circuit 1 is also able to use non-linear amplitude modulation sections 16 and 17.

[0037] The first modulation signal S1 and the second modulation signal S2 are inputted to the combining section 18. The combining section 18 combines the first modulation signal S1 and the second modulation signal S2, and outputs the combined signal as a transmission signal. The combining section 18 is structured by, for example, a Wilkinson combiner, a 3dB directional coupler (hybrid combiner), or a Chireix combiner.

[0038] The transmission circuit 1 uses, e.g., EDGE (Enhanced Datarate GSM Evolution) technology for generating the transmission signal. FIG. 4A shows an exemplary spectrum of the transmission signal which is outputted from the transmission circuit 1 in the case where the EDGE technology is used. In FIG. 4A, a frequency indicated along the horizontal axis represents a shift in a frequency of the transmission signal with respect to a central frequency.

[0039] Also, FIG. 4B shows an exemplary spectrum of the amplitude signal M inputted to the signal separation section 11.

As shown in FIG. 4B, the spectrum of the amplitude signal M extends over a wider frequency range than the spectrum of the transmission signal shown in FIG. 4A. Also, the spectrum of the amplitude signal M indicates that energy concentrates in a low-frequency region. Accordingly, a characteristic of the amplitude signal M is such that energy is small in a high frequency region (i.e., high frequency amplitude signal M_H) and large in the low frequency region (i.e., low frequency amplitude signal M_L). This characteristic is obtained not only in the case where the EDGE technology is used as a modulation method but also in the case where the W-CDMA technology is used as a modulation method. Accordingly, by reducing power to consume when processing the low frequency amplitude signal M_L having large energy, the transmission circuit 1 is able to effectively reduce power consumption thereof. To be specific, it is effective to process the low frequency amplitude signal M_L having large energy, by applying, in the amplitude amplifier 12, a switching regulator or the like which is highly power-efficient.

[0040] Next, the signal separation section 11, the amplitude amplifier 12 and the amplitude modulation sections 16 and 17 will be described in detail.

(signal separation section 11)

FIG. 5 is a block diagram showing in detail an exemplary configuration of the signal separation section 11. As shown in FIG. 5, the signal separation section 11 comprises an input terminal

111, a low-pass filter 112, a dividing section 113 and output terminals 114 and 115. The amplitude signal M is inputted to the low-pass filter 112 and to the dividing section 113 via the input terminal 111. The low-pass filter 112 extracts, from the inputted amplitude signal M, a lower frequency component than a predetermined frequency, and outputs the extracted component from the output terminal 114 as the low frequency amplitude signal M_L. The low frequency amplitude signal M_L is inputted to the dividing section 113. The dividing section 113 divides the amplitude signal M by the low frequency amplitude signal M_L, and outputs a resultant signal from the output terminal 115 as the high frequency amplitude signal M_H.

[0041] (amplitude amplifier 12)

The amplitude amplifier 12 can be structured by, e.g., a series regulator 12a. FIG. 6A is a block diagram showing in detail an exemplary configuration of the series regulator 12a. As shown in FIG. 6A, the series regulator 12a includes an input terminal 121, a comparing section 122, a power source terminal 123, a transistor 124 and an output terminal 125. Here, the transistor 124 is a field-effect transistor. To the input terminal 121, the low frequency amplitude signal M_L is inputted from the signal separation section 11. The low frequency amplitude signal M_L is inputted to a gate terminal of the transistor 124 via the comparing section 122. A drain terminal of the transistor 124 is supplied with a DC voltage from the power source terminal 123.

The transistor 124 outputs, from a source terminal, a voltage proportional to the inputted low frequency amplitude signal M_L. The voltage outputted from the source terminal of the transistor 124 is fed back to the comparing section 122. The comparing section 122 adjusts, based on the fed-back voltage, a magnitude of the low frequency amplitude signal M_L to be inputted to the gate terminal of the transistor 124. In this manner, the series regulator 12a can stably supply, from the output terminal 125, a voltage controlled in accordance with the low frequency amplitude signal M_L. Note that, the transistor 124 may be a bipolar transistor.

[0042] Alternatively, the amplitude amplifier 12 can be structured by, e.g., a switching regulator 12b. FIG. 6B is a block diagram showing in detail an exemplary configuration of the switching regulator 12b. As shown in FIG. 6B, the switching regulator 12b includes an input terminal 121, a power source terminal 123, a signal converting section 126, an amplifying section 127, a low-pass filter 128 and an output terminal 125. To the input terminal 121, the low frequency amplitude signal M_L is inputted from the signal separation section 11. The low frequency amplitude signal M_L is then inputted to the signal converting section 126. The signal converting section 126 converts the inputted low frequency amplitude signal M_L to a signal having been pulse-width modulated or delta-sigma modulated. The signal converted by the signal converting section 126 is inputted to the amplifying section 127. The amplifying section 127 is also

supplied with a DC voltage from the power source terminal 123. The amplifying section 127 amplifies the inputted signal, and then outputs a resultant signal. For the amplifying section 127, a high-efficiency switching amplifier such as a D-class amplifier is used.

[0043] The signal outputted from the amplifying section 127 is inputted to the low-pass filter 128. The low-pass filter 128 removes, from the signal outputted from the amplifying section 127, spurious components such as quantization noise and switching noise. The signal, from which the spurious components have been removed by the low-pass filter 128, is outputted from the output terminal 125 as a voltage controlled in accordance with the low frequency amplitude signal M_L. Note that, the switching regulator 12b may feed the output signal of the low-pass filter 128 back to the signal converting section 126, for the purpose of stabilizing the voltage to be outputted. By using a high-efficiency switching regulator 12b for the amplitude amplifier 12, the transmission circuit 1 can reduce power consumption thereof.

[0044] Still alternatively, the amplitude amplifier 12 can be structured by, e.g., a current-driven regulator 12c. FIG. 6C is a block diagram showing in detail an exemplary configuration of the current-driven regulator 12c. As shown in FIG. 6C, the current-driven regulator 12c includes the input terminal 121, the power source terminal 123, a variable power source 129, transistors 130 and 131, and the output terminal 125. To the input terminal

121, the low frequency amplitude signal M_L is inputted from the signal separation section 11. The power source terminal 123 is supplied with a DC voltage. The low frequency amplitude signal M_L inputted via the input terminal 121 is outputted, as an electric current controlled in accordance with the low frequency amplitude signal M_L, from the output terminal 125 via the variable power source 129 and transistors 130 and 131. The current-driven regulator 12c as described above is useful when the amplitude modulation sections 16 and 17 are each structured by a bipolar transistor. Note that, the transistors 130 and 131 may be field-effect transistor or bipolar transistors.

[0045] (amplitude modulation sections 16 and 17)

The amplitude modulation section 16 can be configured similarly to, e.g., an amplitude modulation section 16a shown in FIG. 7A. FIG. 7A is a block diagram showing in detail an exemplary configuration of the amplitude modulation section 16a. As shown in FIG. 7A, the amplitude modulation section 16a includes an input terminal 161, a matching circuit 162, a bias circuit 163, a power source terminal 164, an input terminal 165, a bias circuit 166, a transistor 167, a matching circuit 168 and an output terminal 169. Here, the transistor 167 is a bipolar transistor. To the input terminal 161, the first angle-modulated signal s1 is inputted from the angle modulation source 14. The first angle-modulated signal s1 is then inputted to a base terminal of the transistor 167 via the matching circuit 162.

[0046] To the power source terminal 164, a DC voltage is applied. In other words, a bias voltage is supplied to the base terminal of the transistor 167 via the bias circuit 163. A signal controlled in accordance with a magnitude of the low frequency amplitude signal M_L is inputted to the input terminal 165 from the amplitude amplifier 12. The signal controlled in accordance with the magnitude of the low frequency amplitude signal M_L is then inputted to a collector terminal of the transistor 167 via the bias circuit 166. The transistor 167 amplitude-modulates the first angle-modulated signal s1 by using the signal controlled in accordance with the magnitude of the low frequency amplitude signal M_L, and outputs a resultant signal as the first modulation signal S1. The first modulation signal S1 outputted from the transistor 167 is outputted from the output terminal 169 via the matching circuit 168. Note that, the transistor 167 may be a field-effect transistor.

[0047] Alternatively, the amplitude modulation section 16 may be structured in a similar manner as that of an amplitude modulation section 16b shown in FIG. 7B. FIG. 7B is a block diagram showing in detail an exemplary configuration of the amplitude modulation section 16b. As shown in FIG. 7B, a fundamental structure of the amplitude modulation section 16b is a result of serially connecting two amplitude modulation sections 16a. Here, the transistor 167 and a transistor 171 are bipolar transistors. The base terminal of the transistor 167 is supplied with the bias voltage from the power source terminal 164 via the bias circuit 163. A base terminal

of the transistor 171 is supplied with a bias voltage from a power source terminal 170 via a bias circuit 174.

[0048] To the collector terminal of the transistor 167, the signal controlled in accordance with the magnitude of the low frequency amplitude signal M_L is inputted from the amplitude amplifier 12 via the input terminal 165 and the bias circuit 166. To a collector terminal of the transistor 171, the signal controlled in accordance with the magnitude of the low frequency amplitude signal M_L is inputted from the amplitude amplifier 12 via the input terminal 165 and a bias circuit 172. By having this structure, the amplitude modulation section 16b is able to output a modulation signal which has a greater dynamic range as compared to the amplitude modulation section 16a shown in FIG. 7A. Note that, the same effect can be obtained even if the transistors 167 and 171 are field effect transistors. Since a configuration of the amplitude modulation section 17 is the same as that of the above-described amplitude modulation section 16, a description thereof will be omitted.

[0049] Note that, in the transmission circuit 1 shown in FIG. 1, the signal controlled in accordance with the low frequency amplitude signal M_L is supplied to each of the amplitude modulation sections 16 and 17 from the common amplitude amplifier 12. However, similarly to a transmission circuit 1a shown in FIG. 8, signals each of which is controlled in accordance with the low frequency amplitude signal M_L may be respectively supplied to the amplitude modulation sections 16 and 17 from different amplitude amplifiers.

FIG. 8 is a block diagram showing an exemplary configuration of the transmission circuit 1a according to the first embodiment of the present invention. In the transmission circuit 1a shown in FIG. 8, the signal controlled in accordance with the low frequency amplitude signal M_L is supplied to the amplitude modulation section 16 from the amplitude amplifier 12 and to the amplitude modulation section 17 from an amplitude amplifier 19. Since a configuration of the amplitude amplifier 19 is the same as that of the above-described amplitude amplifier 12, a description thereof will be omitted.

[0050] As described above, in the transmission circuit 1 according to the first embodiment of the present invention, the low frequency amplitude signal M_L, i.e., a lower frequency component than a predetermined frequency which is extracted from the amplitude signal M, is inputted to the amplitude amplifier 12. As a result, the transmission circuit 1 is able to, even when operating over a wide band, secure a band for the amplitude amplifier 12 and allow the amplitude amplifier 12 to operate with high efficiency. Further, the LINC calculation section 13 outputs the calculation phase signal θ_L by performing a calculation using the high frequency amplitude signal M_H whose envelope variation is small. Therefore, an angle of the calculation phase signal θ_L is small and an angle change thereof is also small. For this reason, a phase difference between the first modulation signal S1 and the second modulation signal S2 is small. Consequently,

when the first modulation signal S1 and the second modulation signal S2 are combined, deterioration of a transmission signal, which is caused by a phase error, and a combining loss can be reduced. Still further, since the envelope of each of the first angle-modulated signal s1 and the second angle-modulated signal s2 is constant, non-linear amplitude modulation sections 16 and 17 can also be used. This allows the transmission circuit 1 to: be small in size; operate with high efficiency; and output a highly linear transmission signal regardless of a bandwidth.

[0051] (second embodiment)

FIG. 9A is a block diagram showing an exemplary configuration of a transmission circuit 2 according to a second embodiment of the present invention. As shown in FIG. 9A, the transmission circuit 2 is different from the transmission circuit 1 of the first embodiment in that angle modulation sources 24 and 25 have different configurations from those of the angle modulation sources 14 and 15. The angle modulation source 24 has a configuration in which angle modulation sections 241 and 242 are serially connected. The angle modulation source 25 has a configuration in which angle modulation sections 251 and 252 are serially connected. Since components other than the angle modulation sources 24 and 25 are the same as those of the first embodiment, descriptions thereof will be omitted. Hereinafter, operations performed by the transmission circuit 2 will be described with reference to FIG. 9A.

[0052] In the angle modulation source 24, the angle modulation section 241 angle-modulates the phase signal θ. The angle modulation section 242 angle-modulates a signal, which results from the angle modulation by the angle modulation section 241, in such a manner that the calculation phase signal θ_L is added to the signal. The angle modulation section 242 then outputs a resultant signal as the first angle-modulated signal s1. Also, in the angle modulation source 25, the angle modulation section 251 angle-modulates the phase signal θ. The angle modulation section 252 angle-modulates a signal, which results from the angle modulation by the angle modulation section 251, in such a manner that the calculation phase signal θ_L is subtracted from the signal. The angle modulation section 252 then outputs a resultant signal as the second angle-modulated signal s2. Note that, in the angle modulation source 24, the angle modulation sections 241 and 242 may be connected in the opposite order. Similarly, in the angle modulation source 25, the angle modulation sections 251 and 252 may be connected in the opposite order.

[0053] Note that, similarly to a transmission circuit 2b shown in FIG. 9B, the angle modulation source 25 may not comprise the angle modulation section 251. In this case, the signal resulting from angle-modulating the phase signal θ is inputted to the angle modulation section 252 from the angle modulation section 241 included in the angle modulation source 24. Further, similarly to a transmission circuit 2c shown in FIG. 9C, the angle modulation

source 24 may not comprise the angle modulation section 241. In this case, the signal resulting from angle-modulating the phase signal θ is inputted to the angle modulation section 242 from the angle modulation section 251 included in the angle modulation source 25. As a result, the transmission circuits 2b and 2c each can be reduced in size.

[0054] The angle modulation sources 24 and 25 according to the second embodiment of the present invention each can be configured as shown in FIG. 10, for example. FIG. 10 is a block diagram showing in detail an exemplary configuration of the angle modulation source 24 according to the second embodiment of the present invention. A characteristic of the angle modulation source 24 shown in FIG. 10 is a configuration of the angle modulation section 242. As shown in FIG. 10, the angle modulation section 242 includes a phase comparator 2421, a LPF (Low-Pass filter) 2422, a voltage controlled oscillator 2423 and a frequency divider 2424. In other words, the angle modulation section 242 is structured by a PLL circuit. The angle modulation section 241 outputs the signal, which results from angle-modulating the phase signal θ, as a reference signal. To the angle modulation section 242, the reference signal is inputted from the angle modulation section 241, and also, a signal which results from differentiating the calculation phase signal θ_L (i.e., $\Delta\theta_L/\Delta t$) is inputted from the LINC calculation section 13.

[0055] In the angle modulation section 242, the reference signal

is inputted to the voltage controlled oscillator 2423 via the phase comparator 2421 and an LPF 2422. The voltage controlled oscillator 2423 controls an oscillatory frequency in accordance with the reference signal. The frequency divider 2424 frequency-divides an output signal of the voltage controlled oscillator 2423 by the signal resulting from differentiating the calculation phase signal θ_L (i.e., $\Delta\theta_L / \Delta t$). The phase comparator 2421 compares a frequency of the inputted reference signal and a frequency of the signal frequency-divided by the frequency divider 2424, and controls the oscillatory frequency of the voltage controlled oscillator 2423 such that the frequencies of the signals are synchronized with each other. The output signal of the voltage controlled oscillator 2423 is outputted from an output terminal as a first frequency-modulated signal s1. Since the angle modulation source 25 has the same configuration as that of the angle modulation source 24 shown in FIG. 10, a description thereof will be omitted.

[0056] As described above, according to the transmission circuit 2 of the second embodiment of the present invention, the same effect as that of the first embodiment can be obtained by having the angle modulation sources 24 and 25 each of which has a configuration in which two angle modulation sections are serially connected.

[0057] (third embodiment)

FIG. 11 is a block diagram showing an exemplary

configuration of a transmission circuit 3 according to a third embodiment of the present invention. As shown in FIG. 11, the transmission circuit 3, as compared to the transmission circuits 1 and 2 according to the first and second embodiments, further comprises a multiplying section 20. Since components of the transmission circuit 3 other than the multiplying section 20 are the same as those described in the first and second embodiments, descriptions thereof will be omitted. To the multiplying section 20 of the transmission circuit 3, the low frequency amplitude signal M_L is inputted from the signal separation section 11, and power information P is inputted from a baseband. The multiplying section 20 outputs a signal, which results from multiplying the low frequency amplitude signal M_L by the power information P, to the amplitude amplifier 12. This allows the transmission circuit 3 to output a transmission signal whose magnitude is controlled in accordance with the power information P.

[0058] Alternatively, the transmission circuit 3 may have a similar configuration to that of a transmission circuit 3a shown in FIG. 12. FIG. 12 is a block diagram showing an exemplary configuration of the transmission circuit 3a according to the third embodiment of the present invention. As shown in FIG. 12, the transmission circuit 3a is different from the transmission circuit 3 shown in FIG. 11 in that an amplitude amplifier 22 has a different configuration from that of the amplitude amplifier 12. The amplitude amplifier 22 has a configuration in which a series

regulator 22a and a switching regulator 22b are serially connected. The power information P is inputted to the multiplying section 20 and to the switching regulator 22b. The multiplying section 20 outputs the signal, which results from multiplying the low frequency amplitude signal M_L by the power information P, to the series regulator 22a. The switching regulator 22b supplies the series regulator 22a with a voltage controlled in accordance with the power information P. To each of the amplitude modulation sections 16 and 17, the series regulator 22a supplies, as a bias voltage, the voltage supplied from the switching regulator 22b, and also supplies a voltage controlled in accordance with the output signal of the multiplying section 20. The series regulator 22a and the switching regulator 22b have the same configurations as those described with reference to FIGs. 6A and 6B.

[0059] Here, the power information P has a low frequency, and therefore allows the switching regulator 22b to operate with high efficiency. Also, the series regulator 22a can operate with high efficiency since the voltage supplied from the switching regulator 22b is optimally controlled. Thus, by using the amplitude amplifier 22 in which the series regulator 22a and the switching regulator 22b are combined, the transmission circuit 3a can further reduce the power consumption thereof. Note that, in the case where the power information P is a digital signal, the amplitude amplifier 22 further includes a DAC for converting the power information P into an analogue signal.

[0060] Alternatively, similarly to a transmission circuit 3b shown in FIG. 13, the transmission circuit 3a may further comprise a lookup table (LUT) 21 positioned between the multiplying section 20 and the amplitude amplifier 22. FIG. 13 is a block diagram showing an exemplary configuration of the transmission circuit 3b according to the third embodiment of the present invention. In FIG. 13, the switching regulator 22b reads an optimal signal from the lookup table 21 in accordance with the power information P, and supplies the series regulator 22a with a voltage controlled in accordance with the read signal.

[0061] As described above, according to the transmission circuit 3 of the third embodiment of the present invention, the multiplying section 20 multiples the low frequency amplitude signal M_L by the power information P. This allows a transmission signal, whose magnitude is controlled in accordance with the power information P, to be outputted.

[0062] (fourth embodiment)

FIG. 14 is a block diagram showing an exemplary configuration of a transmission circuit 4 according to a fourth embodiment of the present invention. As shown in FIG. 14, the transmission circuit 4, as compared to the transmission circuit 3 according to the third embodiment, further comprises a timing control section 23 positioned previous to the amplitude amplifier 22. FIG. 15 is an exemplary timing chart of signals used in the transmission circuit 4. Hereinafter, operations performed by the

transmission circuit 4 according to the fourth embodiment will be described with reference to FIG. 15. To the signal separation section 11, the amplitude signal M is inputted (see FIG. 15(a)). To the timing control section 23, the power information P is inputted (see FIG. 15(b)). In order to compensate for rising of the switching regulator 22b, the timing control section 23 advances a timing of outputting the power information P by Δtx, and then outputs the power information as power information Px(t) (see FIG. 15(c)).

[0063] The power information Px(t) is inputted to the switching regulator 22b. The switching regulator 22b outputs a voltage Vy(t) controlled by the power information Px(t) (see FIG. 15(d)). The voltage Vy(t) outputted from the switching regulator 22b is supplied to the series regulator 22a. Based on the supplied voltage, the series regulator 22a outputs a voltage Vz(t) controlled in accordance with the low frequency amplitude signal M_L (see FIG. 15(e)). The voltage Vz(t) outputted from the series regulator 22a is supplied to each of the amplitude modulation sections 16 and 17.

[0064] Note that, instead of advancing, by the timing control section 23, the timing of outputting the power information P by Δtx, the signal separation section 11 may delay timings of outputting the low frequency amplitude signal M_L and the high frequency amplitude signal M_H by Δtx.

[0065] As described above, according to the transmission

circuit 4 of the fourth embodiment of the present invention, the amplitude amplifier 22, which is a combination of the switching regulator 22b capable of operating with high efficiency and the series regulator 22a capable of operating with a high speed, controls a voltage to be supplied to each of the amplitude modulation sections 16 and 17. As a result, the transmission circuit 4 is able to operate with higher efficiency and speed than the transmission circuit 1 according to the first embodiment.

[0066] The transmission circuits 1 to 4 according to the above first to fourth embodiments each may further comprise a distortion compensation section 26 for compensating for AM-PM distortion or AM-AM distortion which occurs in at least either one of the amplitude amplifier 12, the amplitude modulation section 16 and the amplitude modulation section 17. FIG. 16 is a block diagram showing an exemplary configuration of a transmission circuit 1x according to the first embodiment, the transmission circuit 1x comprising the distortion compensation section 26. In FIG. 16, the distortion compensation section 26 compensates for at least the amplitude signal M or the phase signal θ, so as to suppress the AM-PM distortion or AM-AM distortion which occurs in at least either one of the amplitude amplifier 12, the amplitude modulation section 16 and the amplitude modulation section 17. This allows the transmission circuit 1x to improve linearity of the transmission signal as compared to the transmission circuits according to the above first to fourth embodiments.

[0067] Alternatively, similarly to, e.g., a transmission circuit 1y shown in FIG. 17A, the transmission circuits 1 to 4 according to the above first to fourth embodiments each may comprise a band-pass filter (BPF) 27 positioned subsequent to the amplitude modulation section 16 and a band-pass filter (BPF) 28 positioned subsequent to the amplitude modulation section 17. Further alternatively, similarly to, e.g., a transmission circuit 1z shown in FIG. 17B, the transmission circuits 1 to 4 according to the above first to fourth embodiments each may comprise a band-pass filter (BPF) 29 positioned subsequent to the combining section 18. In this case, similarly to the switching regulator 12d shown in FIG. 17C, there is no necessity for a switching regulator used for the amplitude amplifier 12 of the transmission circuits 1y and 1z to have a low-pass filter positioned subsequent to the amplifying section 127.

[0068] The transmission circuits 3 and 4 according to the above third and fourth embodiments each may have a configuration in which the amplitude amplifier 22 is replaced with a current-driven amplitude amplifier 30, similarly to, e.g., transmission circuits 3x, 3y and 4x shown in FIGs. 18A to 18C. In the amplitude amplifier 30, a current-driven regulator 30a supplies each of the amplitude modulation sections 16 and 17 with an electric current controlled in accordance with the low frequency amplitude signal M_L. A current-driven regulator 30b supplies each of the amplitude modulation sections 16 and 17 with an electric current controlled

in accordance with the power information P. The current-driven regulator 30b can reduce the power consumption thereof by using a switching mode. Here, the current-driven regulators 30a and 30b each have the same configuration as that described with reference to FIG. 6C. The current-driven amplitude amplifier 30 as described above is useful when the amplitude modulation sections 16 and 17 are structured by bipolar transistors.

[0069] (fifth embodiment)

FIG. 19 is a block diagram showing an exemplary structure of a communication device according to a fifth embodiment of the present invention. As shown in FIG. 19, a communication device 200 according to the fifth embodiment comprises a transmission circuit 210, reception circuit 220, antenna duplexer 230 and an antenna 240. The transmission circuit 210 is any one of the transmission circuits described in the above first to fourth embodiments. The antenna duplexer 230 transmits to the antenna 240 a transmission signal outputted from the transmission circuit 210, and prevents the transmission signal from leaking to the reception circuit 220. Also, the antenna duplexer 230 transmits to the reception circuit 220 a reception signal inputted from the antenna 240, and prevents the reception signal from leaking to the transmission circuit 210. Accordingly, the transmission signal is outputted from the transmission circuit 210, and released from the antenna 240 to the exterior space via the antenna duplexer 230. The reception signal is received by the antenna 240, and

then received by the reception circuit 220 via the antenna duplexer 230. The communication device 200 according to the fifth embodiment uses any of the transmission circuits according to the first to fourth embodiments, thereby securing the linearity of the transmission signal and also realizing low distortion as a radio device. Since there is no branching element, such as a directional coupler, on an output of the transmission circuit 210, loss from the transmission circuit 210 to the antenna 240 is reduced, whereby power consumption at the time of transmission is reduced. As a result, the communication device 200 is capable of operating for a long period of time as a radio communication device. Note that, the communication device 200 may have a structure which includes only the transmission circuit 210 and antenna 240.

INDUSTRIAL APPLICABILITY

[0070] The transmission circuits according to the present invention are applicable to, e.g., communication devices such as mobile phones and wireless LAN devices.

CLAIMS

[1] A transmission circuit for generating a transmission signal based on an input amplitude signal and an input phase signal, and outputting the transmission signal, the transmission circuit comprising:

a signal separation section for separating the input amplitude signal into a high-frequency amplitude signal and a low-frequency amplitude signal;

an amplitude amplifier for outputting a signal controlled in accordance with the low-frequency amplitude signal;

a LINC calculation section for outputting, based on a predetermined calculation using the high-frequency amplitude signal, a calculation phase signal whose phase changes in accordance with the high-frequency amplitude signal;

a first angle modulation source for generating a first angle-modulated signal by angle-modulating the input phase signal and the calculation phase signal in such a manner that the calculation phase signal is added to the input phase signal;

a second angle modulation source for generating a second angle-modulated signal by angle-modulating the input phase signal and the calculation phase signal in such a manner that the calculation phase signal is subtracted from the input phase signal;

a first amplitude modulation section for amplitude-modulating the first angle-modulated signal by using the signal outputted from the amplitude amplifier, and outputting

a resultant signal as a first modulation signal;

a second amplitude modulation section for amplitude-modulating the second angle-modulated signal by using the signal outputted from the amplitude amplifier, and outputting a resultant signal as a second modulation signal; and

a combining section for combining the first modulation signal and the second modulation signal, and outputting a resultant signal as the transmission signal, wherein

the LINC calculation section outputs, as the calculation phase signal, arccosine of a value obtained by dividing the high-frequency amplitude signal by a constant value.

[2] The transmission circuit according to claim 1, wherein the signal separation section extracts, from the input amplitude signal, a lower frequency component than a predetermined frequency, and outputs the extracted component as the low-frequency amplitude signal, and outputs the high-frequency amplitude signal which results from dividing the input amplitude signal by the low-frequency amplitude signal.

[3] The transmission circuit according to claim 1, wherein the signal separation section includes:

a low-pass filter for extracting, from the input amplitude signal, a lower frequency component than a predetermined frequency, and outputting the extracted component as the

low-frequency amplitude signal; and

a dividing section for outputting the high-frequency amplitude signal which results from dividing the input amplitude signal by the low-frequency amplitude signal.

[4] The transmission circuit according to clam 1, wherein the first angle modulation source includes:

an addition section for outputting a signal resulting from adding the calculation phase signal to the input phase signal; and

a first angle modulation section for angle-modulating the signal outputted from the addition section, and outputting a resultant signal as the first angle-modulated signal, and

the second angle modulation source includes:

a subtraction section for outputting a signal resulting from subtracting the calculation phase signal from the input phase signal; and

a second angle modulation section for angle-modulating the signal outputted from the subtraction section, and outputting a resultant signal as the second angle-modulated signal.

[5] The transmission circuit according to claim 1, wherein the first angle modulation source includes:

a first angle modulation section for angle-modulating the input phase signal; and

a second angle modulation section for angle-modulating a signal, which has been angle-modulated by the first angle modulation section, in such a manner that the calculation phase signal is added to the signal, and outputting a resultant signal as the first angle-modulated signal, and

the second angle modulation source includes:

a third angle modulation section for angle-modulating the input phase signal; and

a fourth angle modulation section for angle-modulating a signal, which has been angle-modulated by the third angle modulation section, in such a manner that the calculation phase signal is subtracted from the signal, and outputting a resultant signal as the second angle-modulated signal.

[6] The transmission circuit according to claim 1, wherein the amplitude amplifier is structured by a switching regulator, and supplies each of the first and second amplitude modulation sections with a voltage which is controlled in accordance with the low-frequency amplitude signal.

[7] The transmission circuit according to claim 1, wherein the amplitude amplifier is structured by a series regulator, and supplies each of the first and second amplitude modulation sections

with a voltage which is controlled in accordance with the low-frequency amplitude signal.

[8] The transmission circuit according to claim 1, further comprising a multiplying section for multiplying the low-frequency amplitude signal by power information inputted from a baseband, which multiplying section is positioned between the signal separation section and the amplitude amplifier.

[9] The transmission circuit according to claim 8, wherein

the amplitude amplifier has a configuration in which a switching regulator and a series regulator are serially connected,

the switching regulator supplies the series regulator with a voltage which is controlled in accordance with the power information inputted from the baseband, and

to each of the first and second modulation sections, the series regulator supplies, as a bias voltage, the voltage supplied from the switching regulator, and also supplies a voltage which is controlled in accordance with an output signal of the multiplying section.

[10] The transmission circuit according to claim 1, further comprising a distortion compensation section for compensating for AM-PM distortion or AM-AM distortion which occurs in at least either

one of the amplitude amplifier, the first amplitude modulation section and the second amplitude modulation section.

[11] A communication device comprising:

a transmission circuit for generating a transmission signal; and

an antenna for outputting the transmission signal generated by the transmission circuit, wherein

the transmission circuit is the transmission circuit according to claim 1.

[12] The communication device according to claim 11, further comprising:

a reception circuit for processing a reception signal received from the antenna; and

an antenna duplexer for outputting the transmission signal generated by the transmission circuit to the antenna, and outputting the reception signal received from the antenna to the reception circuit.

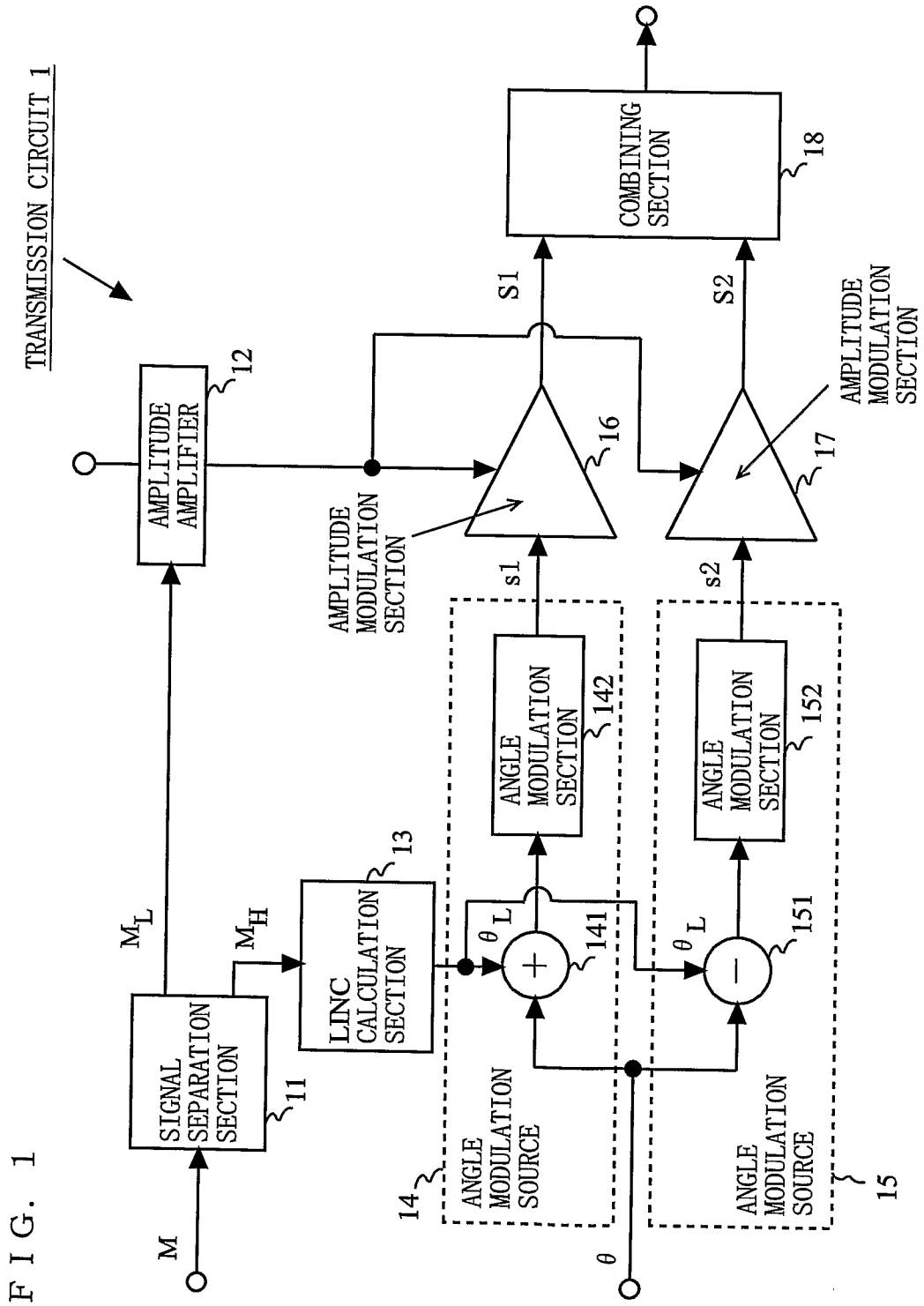

TRANSMISSION CIRCUIT 1
M
SIGNAL SEPARATION SECTION
11
M_L
M_H
AMPLITUDE AMPLIFIER
12
LINC CALCULATION SECTION
13
ANGLE MODULATION SOURCE
14
θ
θ_L
141
ANGLE MODULATION SECTION
142
s1
AMPLITUDE MODULATION SECTION
16
S1
COMBINING SECTION
18
ANGLE MODULATION SOURCE
15
θ_L
151
ANGLE MODULATION SECTION
152
s2
AMPLITUDE MODULATION SECTION
17
S2

FIG. 1

FIG. 2

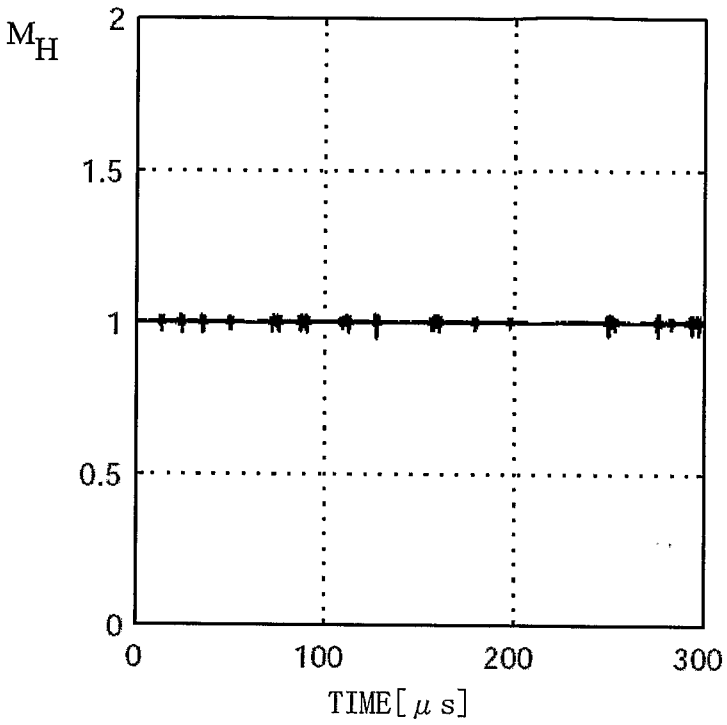


FIG. 3

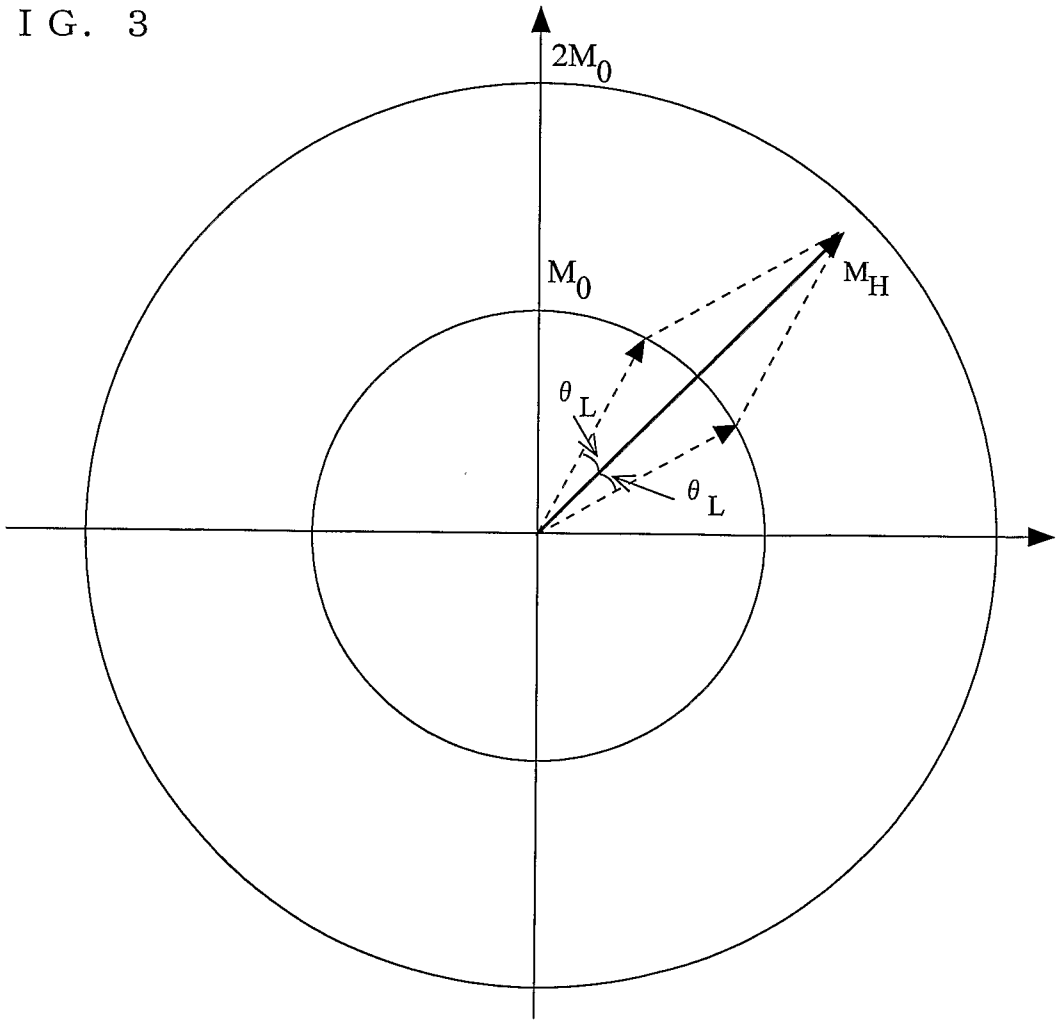


FIG. 4A

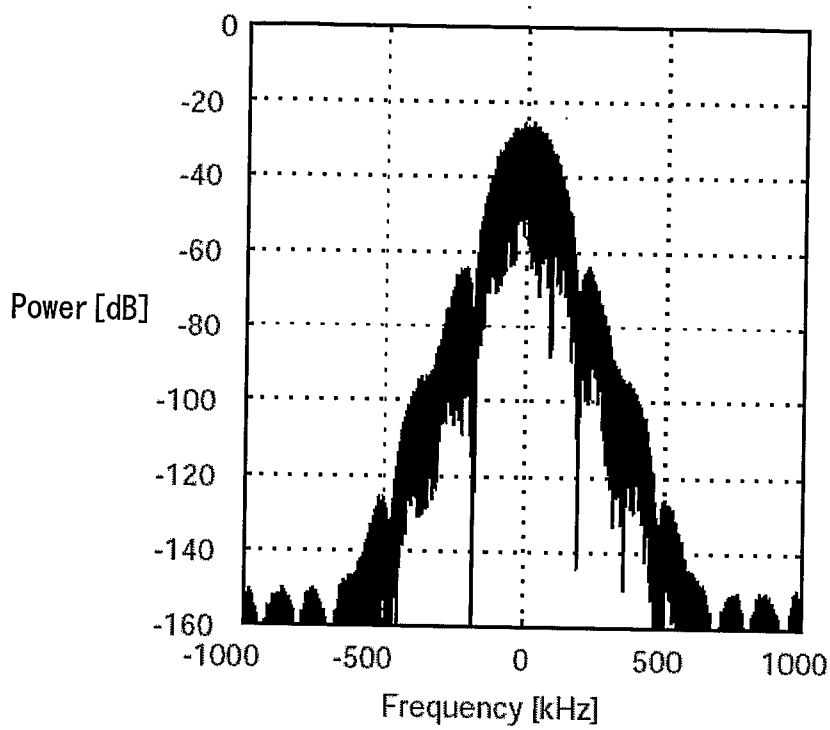

0
-20
-40
-60
-80
-100
-120
-140
-160
Power [dB]
-1000
-500
0
500
1000
Frequency [kHz]

FIG. 4B

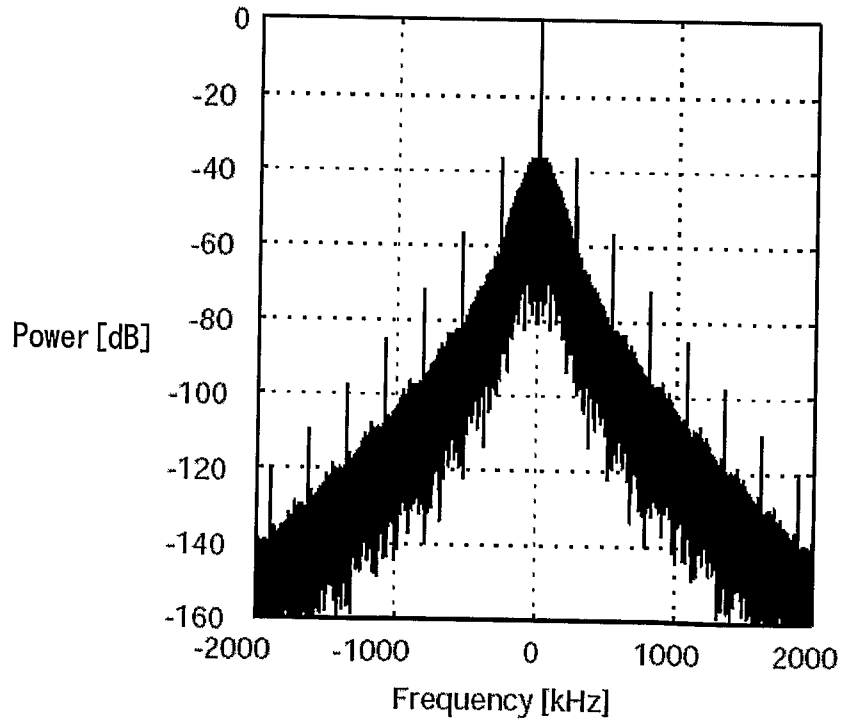

0
-20
-40
-60
-80
-100
-120
-140
-160
Power [dB]
-2000
-1000
0
1000
2000
Frequency [kHz]

FIG. 5

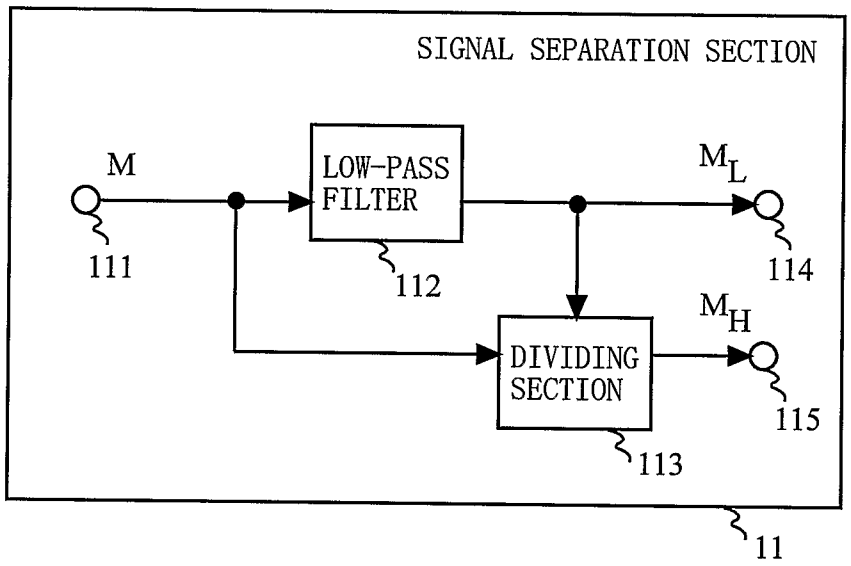

SIGNAL SEPARATION SECTION
M
111
LOW-PASS FILTER
112
M_L
114
M_H
DIVIDING SECTION
113
115
11

FIG. 6A

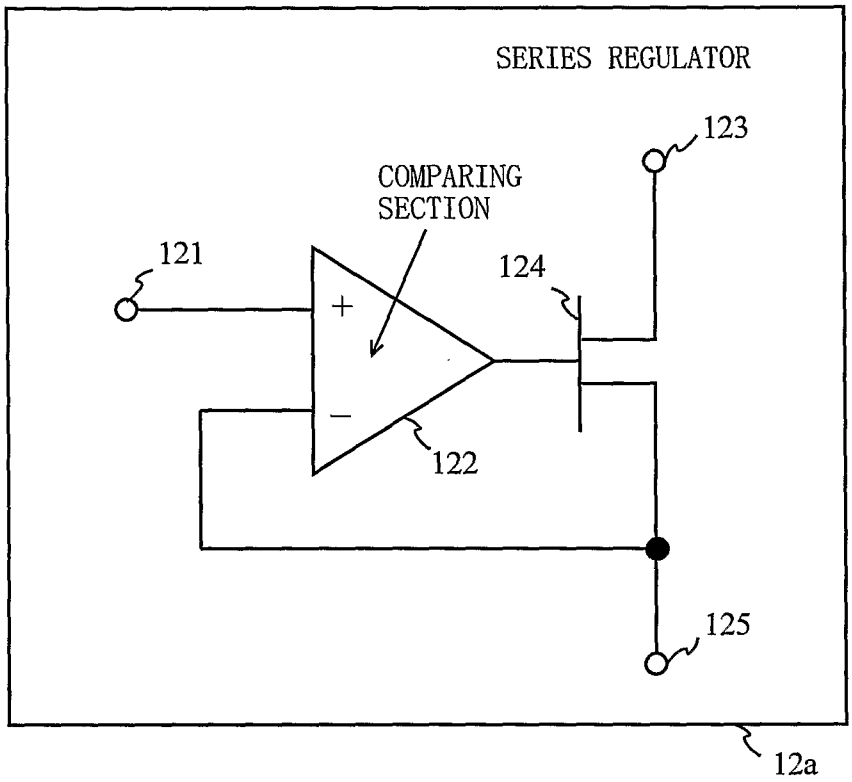

SERIES REGULATOR
123
COMPARING
SECTION
121
124
+
−
122
125
12a

FIG. 6B

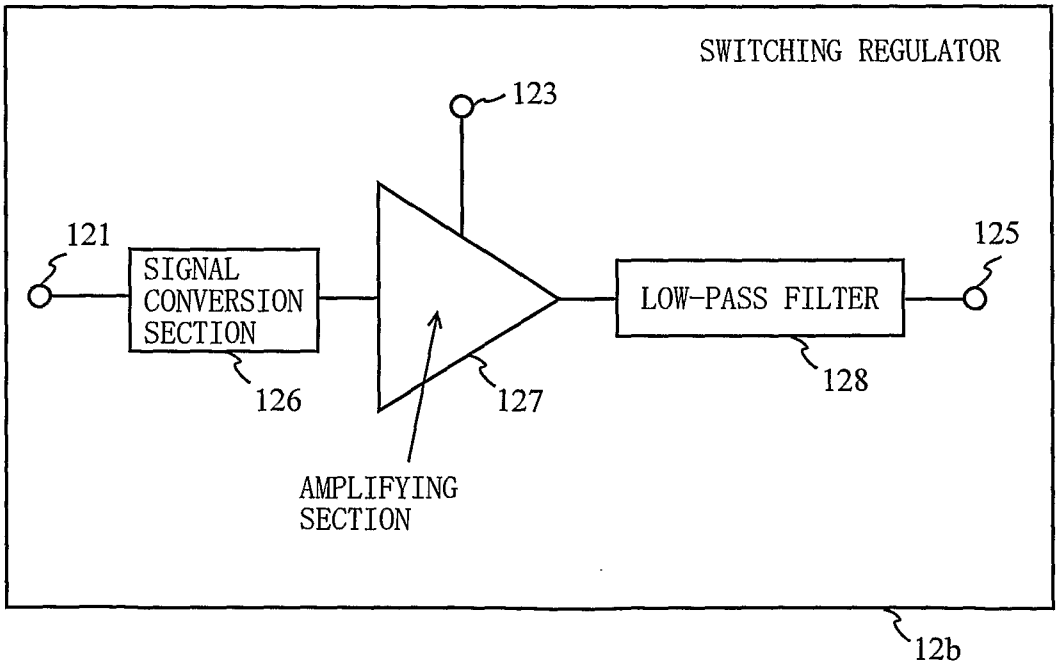

SWITCHING REGULATOR
123
121
SIGNAL
CONVERSION
SECTION
126
127
LOW-PASS FILTER
128
125
AMPLIFYING
SECTION
12b

FIG. 6C

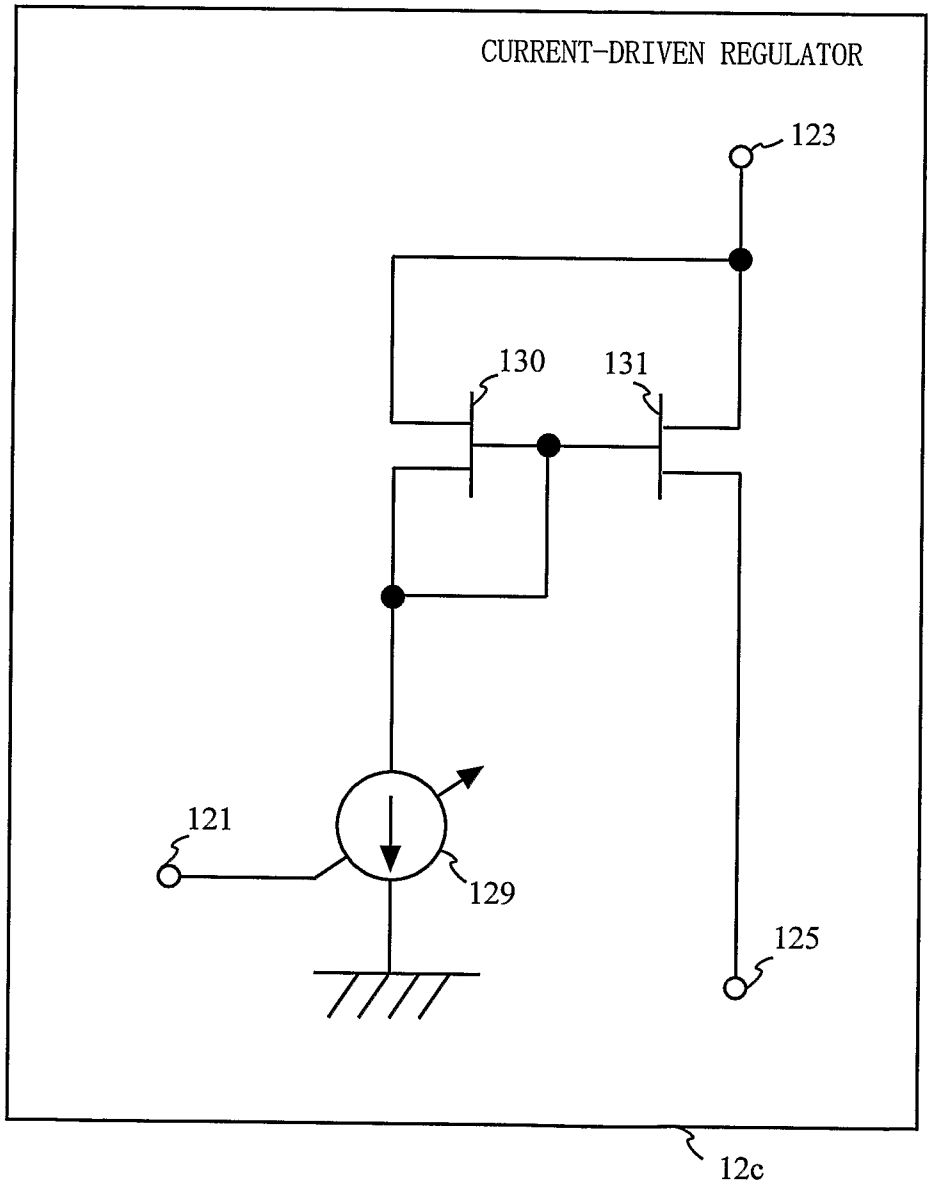


FIG. 7A

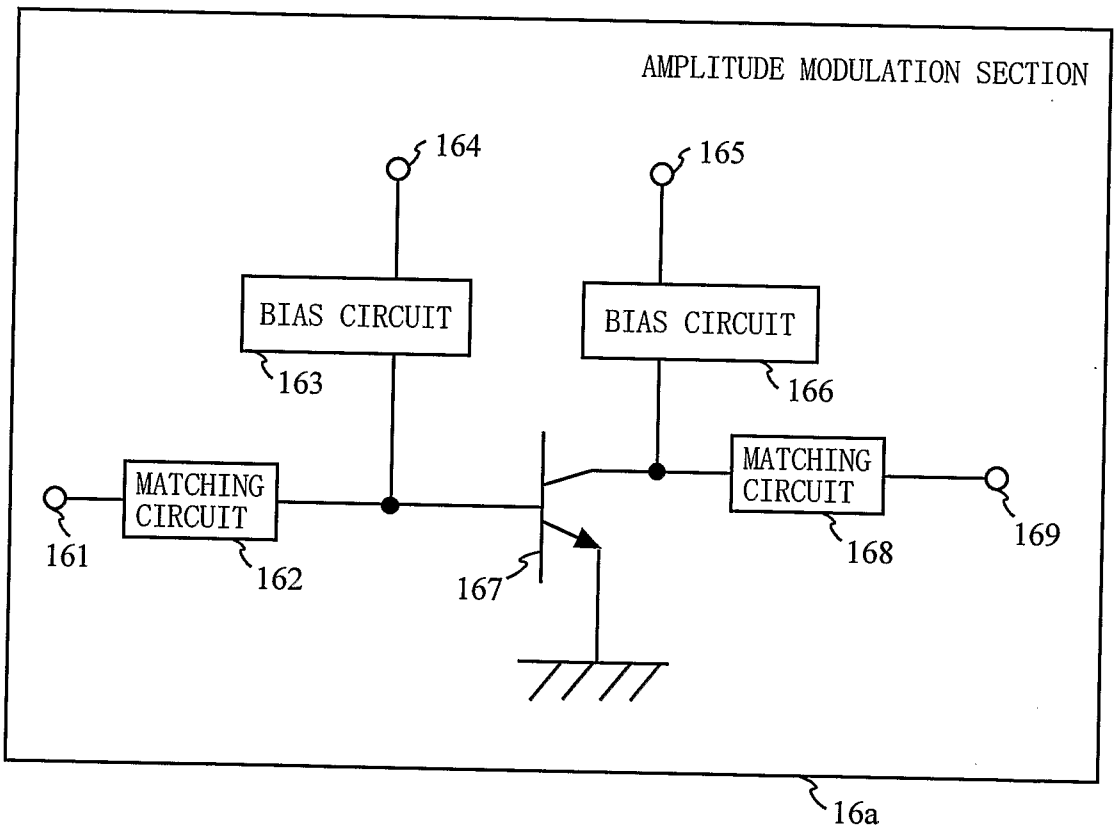

AMPLITUDE MODULATION SECTION
164
165
BIAS CIRCUIT
163
BIAS CIRCUIT
166
MATCHING CIRCUIT
161
162
MATCHING CIRCUIT
168
169
167
16a

FIG. 7B

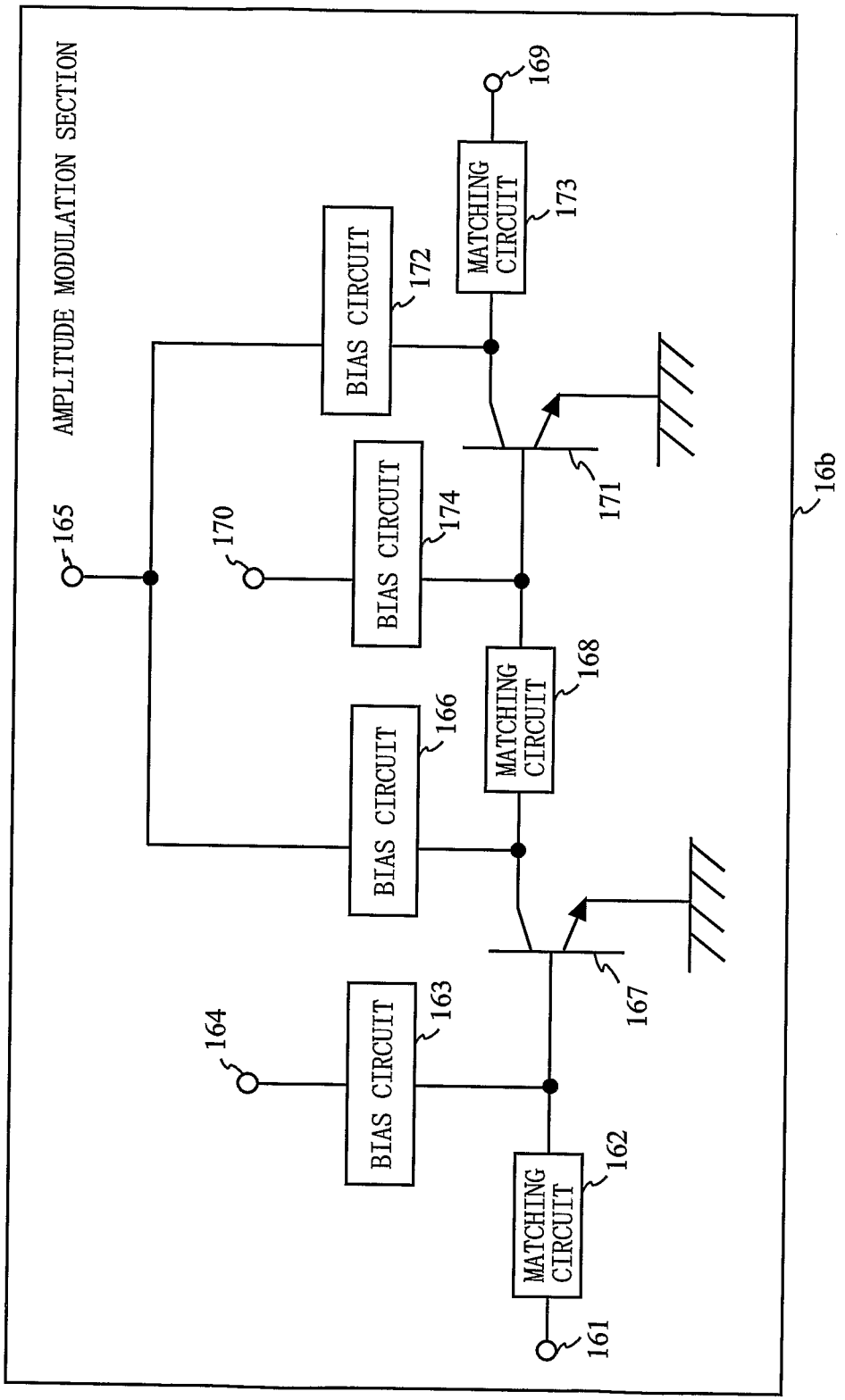
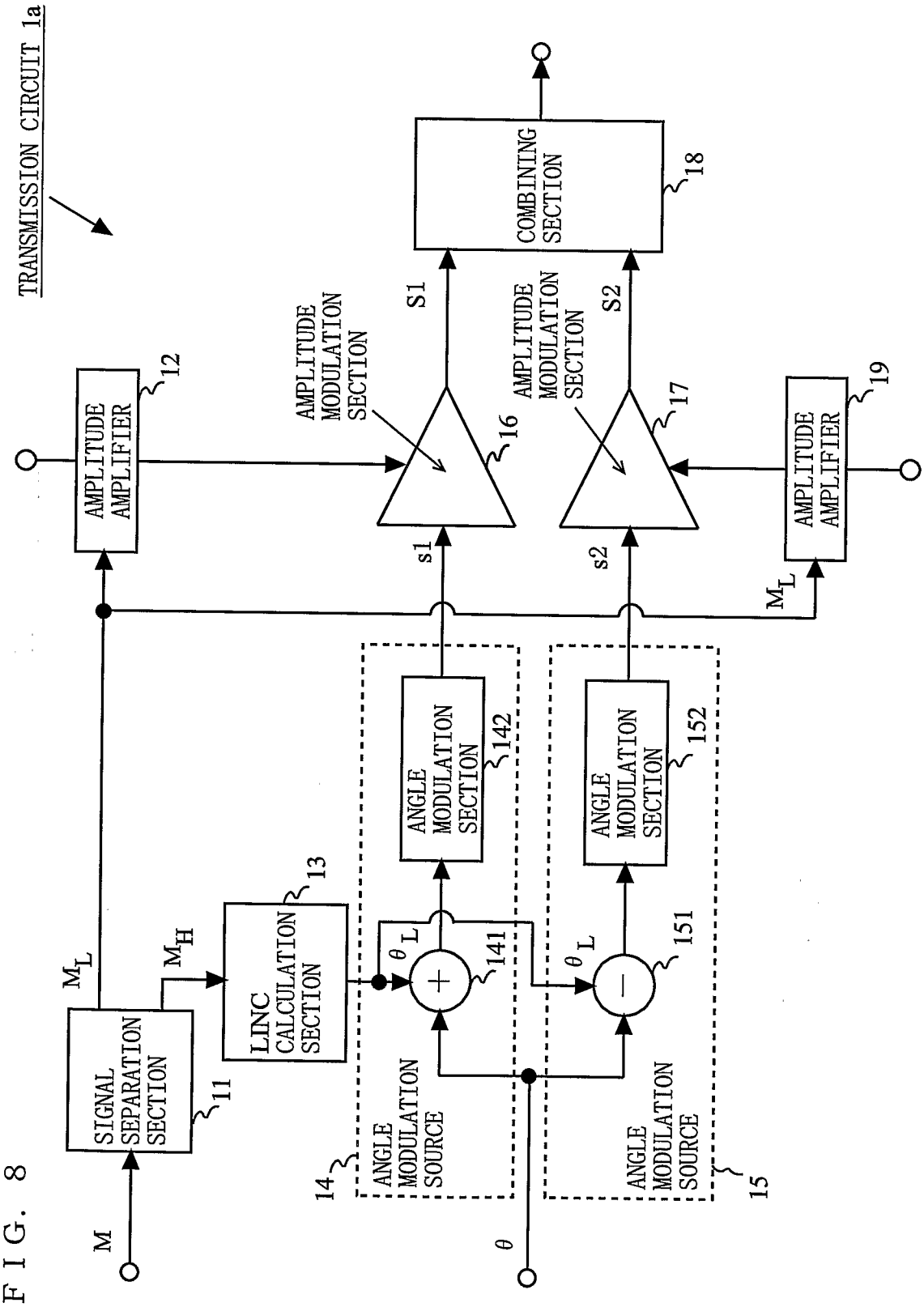

AMPLITUDE MODULATION SECTION
16b
161
MATCHING CIRCUIT
162
BIAS CIRCUIT
163
164
167
BIAS CIRCUIT
166
MATCHING CIRCUIT
168
BIAS CIRCUIT
174
170
165
171
BIAS CIRCUIT
172
MATCHING CIRCUIT
173
169

FIG. 8


TRANSMISSION CIRCUIT 1a
M
SIGNAL SEPARATION SECTION
11
M_L
M_H
LINC CALCULATION SECTION
13
θ_L
141
ANGLE MODULATION SECTION
142
ANGLE MODULATION SOURCE
14
θ
θ_L
151
ANGLE MODULATION SECTION
152
ANGLE MODULATION SOURCE
15
AMPLITUDE AMPLIFIER
12
AMPLITUDE MODULATION SECTION
16
s1
S1
AMPLITUDE MODULATION SECTION
17
s2
S2
COMBINING SECTION
18
AMPLITUDE AMPLIFIER
19
M_L

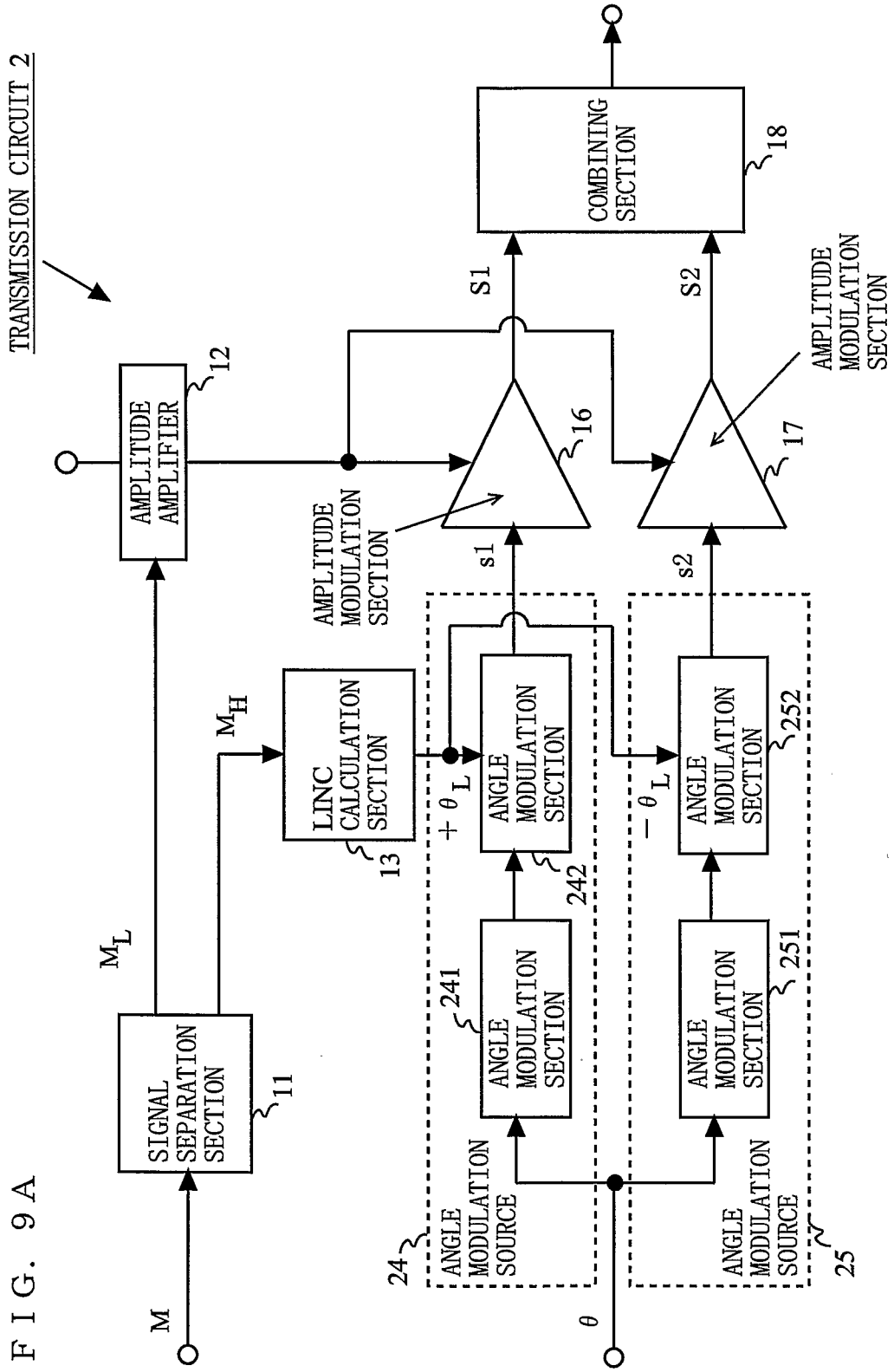

TRANSMISSION CIRCUIT 2
AMPLITUDE AMPLIFIER
12
SIGNAL SEPARATION SECTION
11
M
M_L
M_H
LINC CALCULATION SECTION
13
AMPLITUDE MODULATION SECTION
16
17
AMPLITUDE MODULATION SECTION
COMBINING SECTION
18
S1
S2
s1
s2
$+\theta_L$
$-\theta_L$
ANGLE MODULATION SECTION
241
242
251
252
ANGLE MODULATION SOURCE
24
25
θ

FIG. 9A

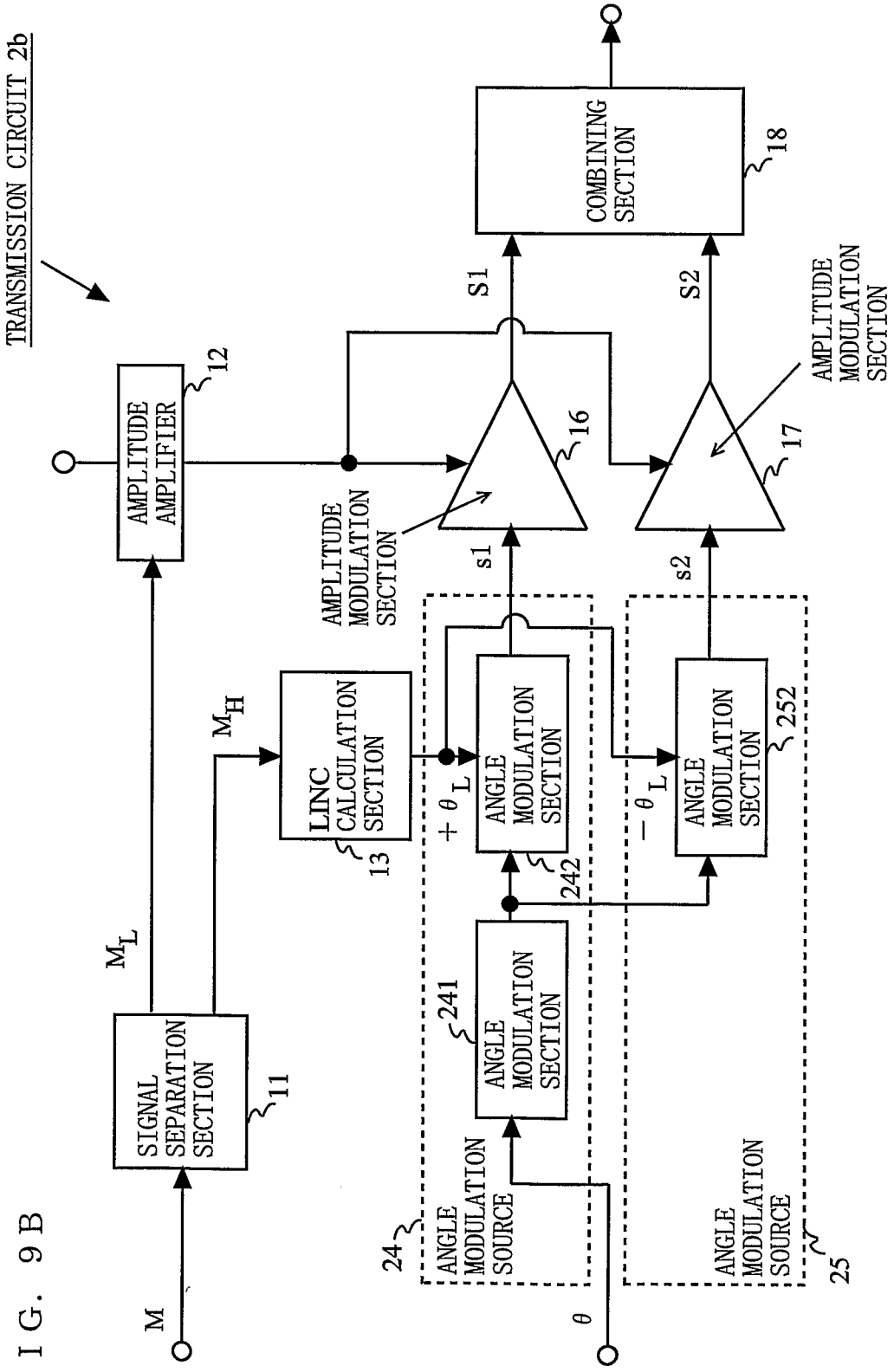

TRANSMISSION CIRCUIT 2b
M
SIGNAL SEPARATION SECTION
11
M_L
M_H
AMPLITUDE AMPLIFIER
12
LINC CALCULATION SECTION
13
AMPLITUDE MODULATION SECTION
ANGLE MODULATION SOURCE
24
ANGLE MODULATION SECTION
241
ANGLE MODULATION SECTION
242
$+\theta_L$
$-\theta_L$
s1
s2
16
17
AMPLITUDE MODULATION SECTION
S1
S2
COMBINING SECTION
18
ANGLE MODULATION SECTION
252
ANGLE MODULATION SOURCE
25
θ

FIG. 9B

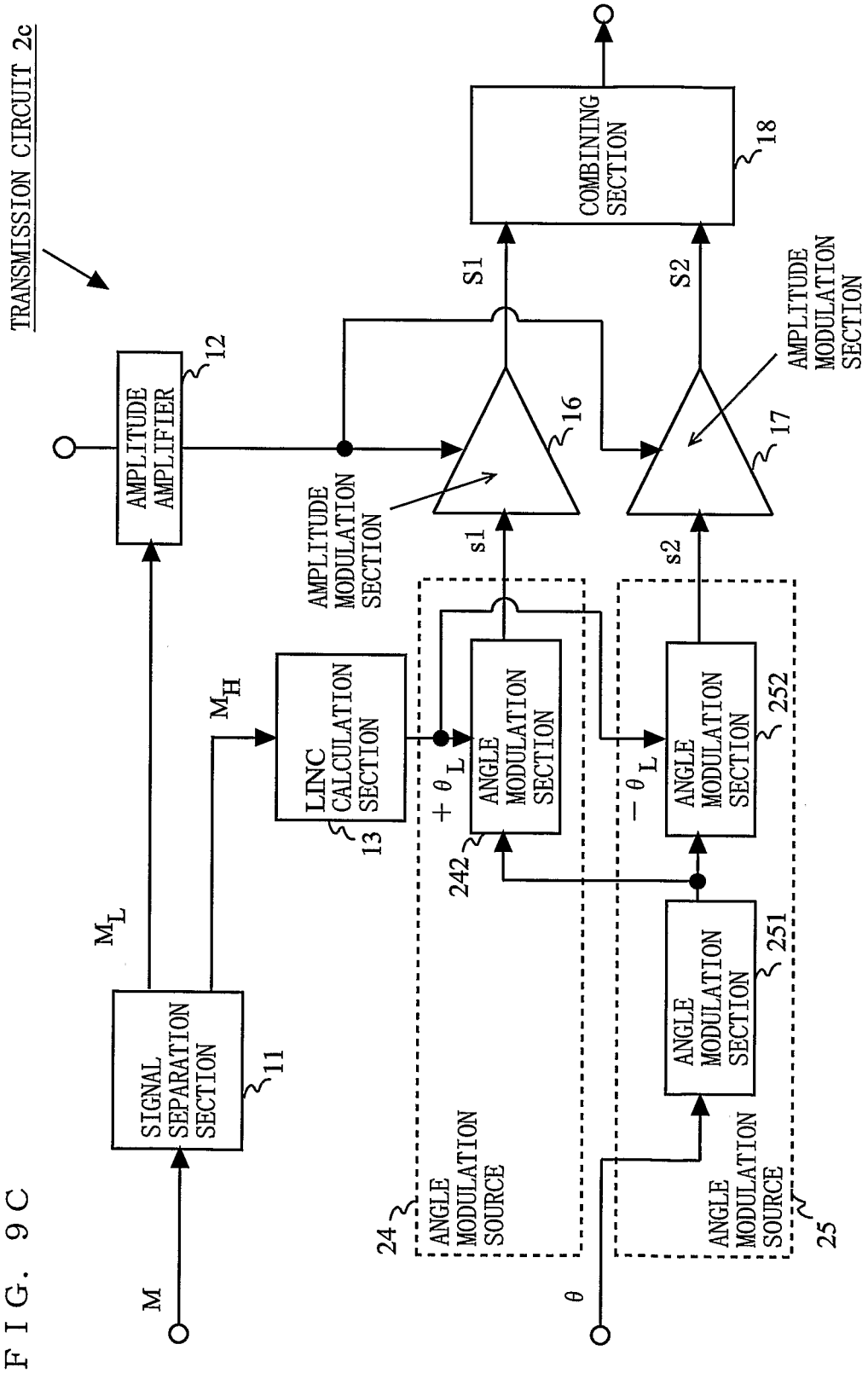
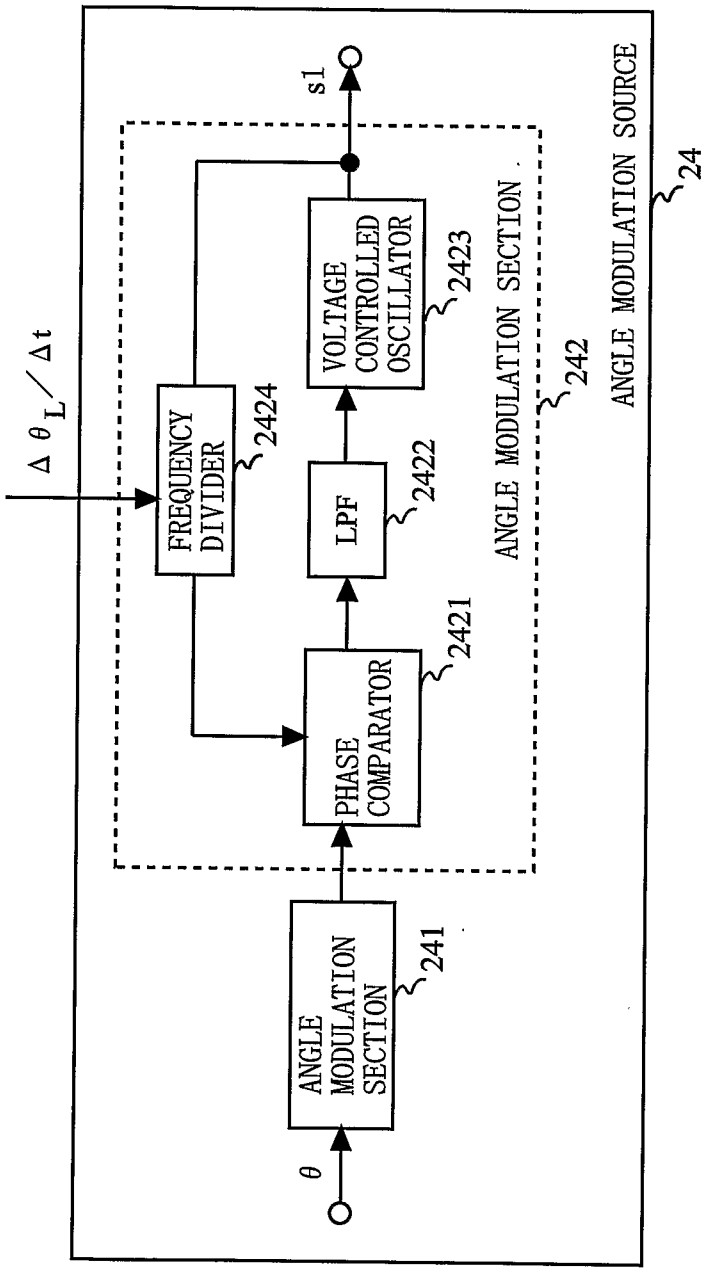

TRANSMISSION CIRCUIT 2c
SIGNAL SEPARATION SECTION
11
AMPLITUDE AMPLIFIER
12
LINC CALCULATION SECTION
13
AMPLITUDE MODULATION SECTION
16
AMPLITUDE MODULATION SECTION
17
COMBINING SECTION
18
ANGLE MODULATION SECTION
242
ANGLE MODULATION SECTION
251
ANGLE MODULATION SECTION
252
ANGLE MODULATION SOURCE
24
ANGLE MODULATION SOURCE
25
M
M_L
M_H
S1
S2
s1
s2
$+\theta_L$
$-\theta_L$
θ

FIG. 9C

FIG. 10


θ
ANGLE MODULATION SECTION
241
PHASE COMPARATOR
2421
LPF
2422
VOLTAGE CONTROLLED OSCILLATOR
2423
FREQUENCY DIVIDER
2424
Δθ_L / Δt
ANGLE MODULATION SECTION
242
s1
ANGLE MODULATION SOURCE
24

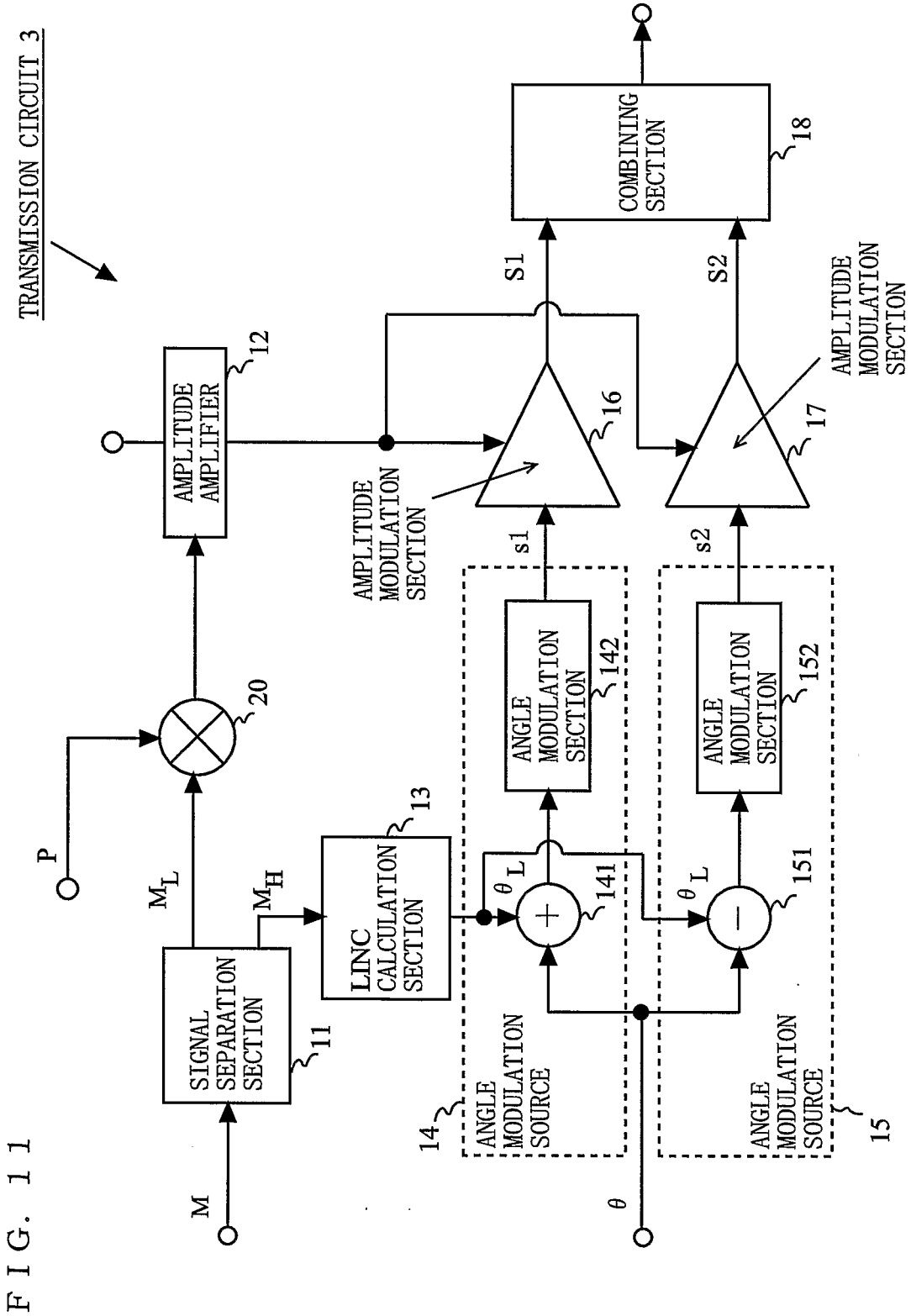

TRANSMISSION CIRCUIT 3
AMPLITUDE AMPLIFIER
12
SIGNAL SEPARATION SECTION
11
LINC CALCULATION SECTION
13
ANGLE MODULATION SOURCE
14
ANGLE MODULATION SOURCE
15
AMPLITUDE MODULATION SECTION
16
AMPLITUDE MODULATION SECTION
17
COMBINING SECTION
18
ANGLE MODULATION SECTION
142
ANGLE MODULATION SECTION
152
20
141
151
M
P
M_L
M_H
θ_L
θ_L
θ
S1
S2
s1
s2

FIG. 11

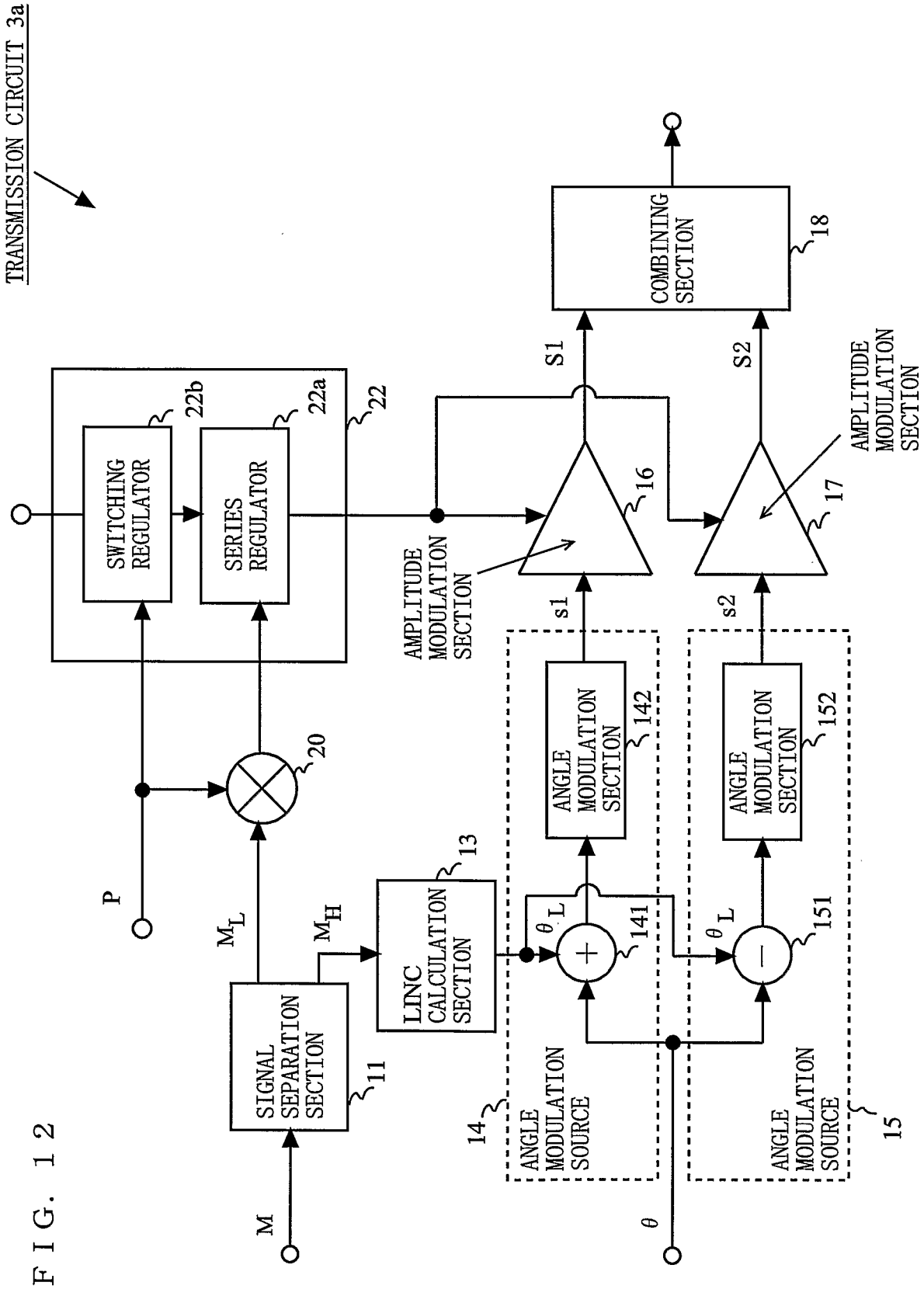
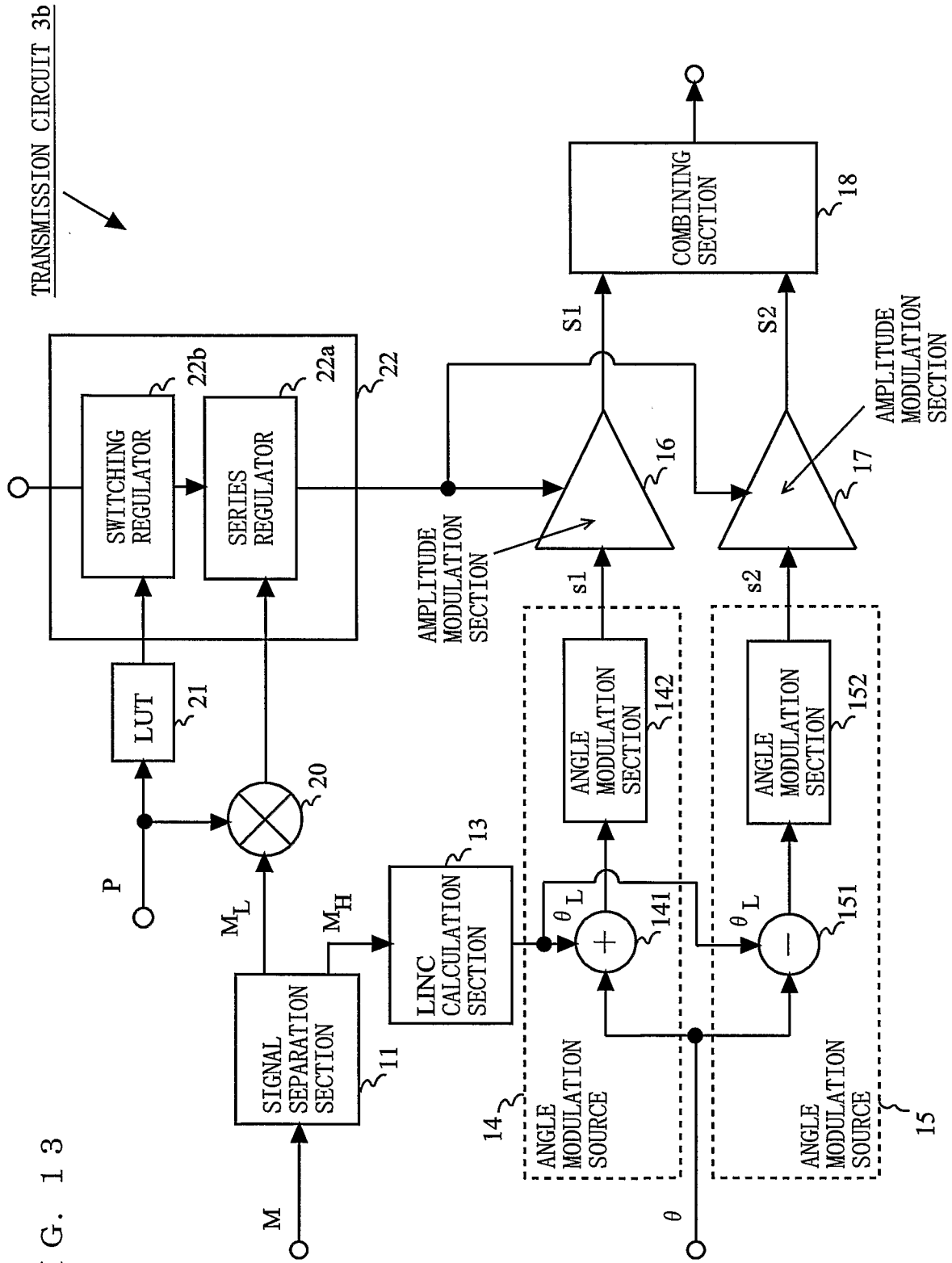

TRANSMISSION CIRCUIT 3a
SWITCHING REGULATOR
22b
SERIES REGULATOR
22a
22
AMPLITUDE MODULATION SECTION
S1
S2
COMBINING SECTION
18
16
17
AMPLITUDE MODULATION SECTION
s1
s2
ANGLE MODULATION SECTION
142
ANGLE MODULATION SECTION
152
20
P
M_L
M_H
LINC CALCULATION SECTION
13
θ_L
141
θ_L
151
SIGNAL SEPARATION SECTION
11
M
14
ANGLE MODULATION SOURCE
ANGLE MODULATION SOURCE
15
θ

FIG. 12

FIG. 13


TRANSMISSION CIRCUIT 3b
SWITCHING REGULATOR
22b
SERIES REGULATOR
22a
22
LUT
21
20
P
M
SIGNAL SEPARATION SECTION
11
M_L
M_H
LINC CALCULATION SECTION
13
θ_L
141
ANGLE MODULATION SECTION
142
s1
ANGLE MODULATION SOURCE
14
θ
θ_L
151
ANGLE MODULATION SECTION
152
s2
ANGLE MODULATION SOURCE
15
AMPLITUDE MODULATION SECTION
16
AMPLITUDE MODULATION SECTION
17
S1
S2
COMBINING SECTION
18

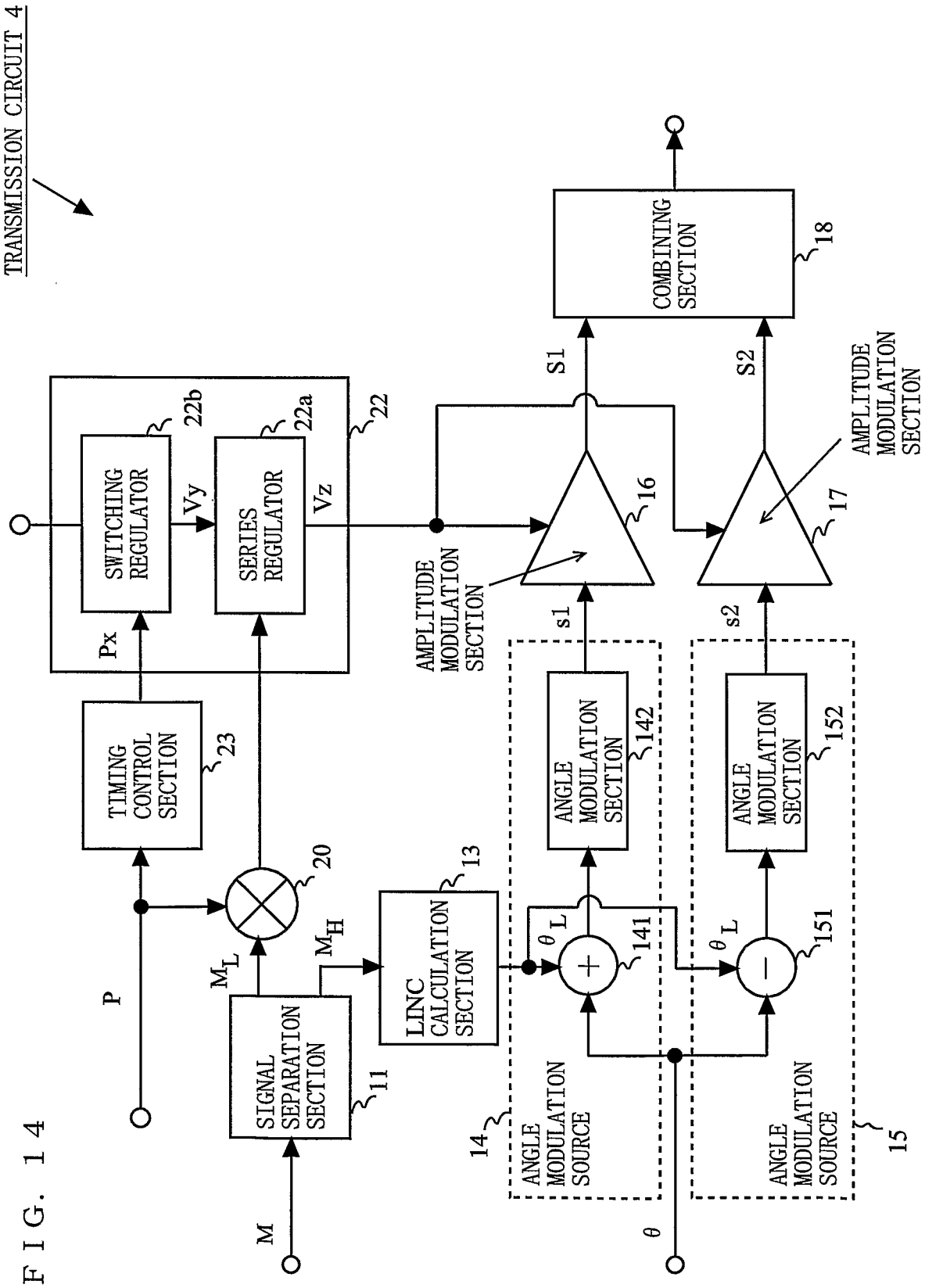
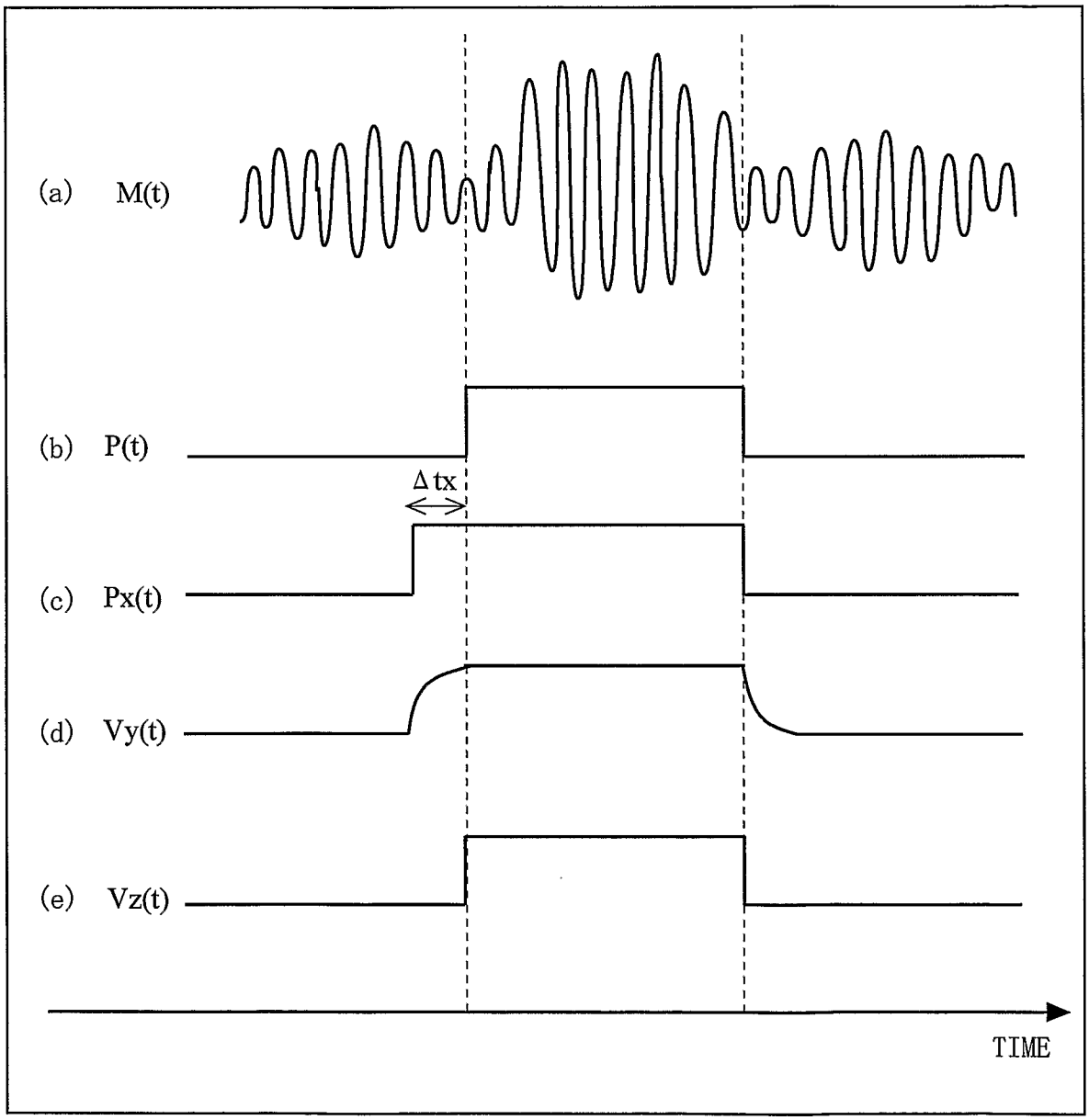

TRANSMISSION CIRCUIT 4
SWITCHING REGULATOR
22b
Vy
SERIES REGULATOR
22a
Vz
22
Px
TIMING CONTROL SECTION
23
P
20
M_L
M_H
SIGNAL SEPARATION SECTION
11
M
LINC CALCULATION SECTION
13
θ_L
141
ANGLE MODULATION SECTION
142
s1
ANGLE MODULATION SOURCE
14
θ
θ_L
151
ANGLE MODULATION SECTION
152
s2
ANGLE MODULATION SOURCE
15
AMPLITUDE MODULATION SECTION
16
S1
AMPLITUDE MODULATION SECTION
17
S2
COMBINING SECTION
18

FIG. 14

FIG. 15



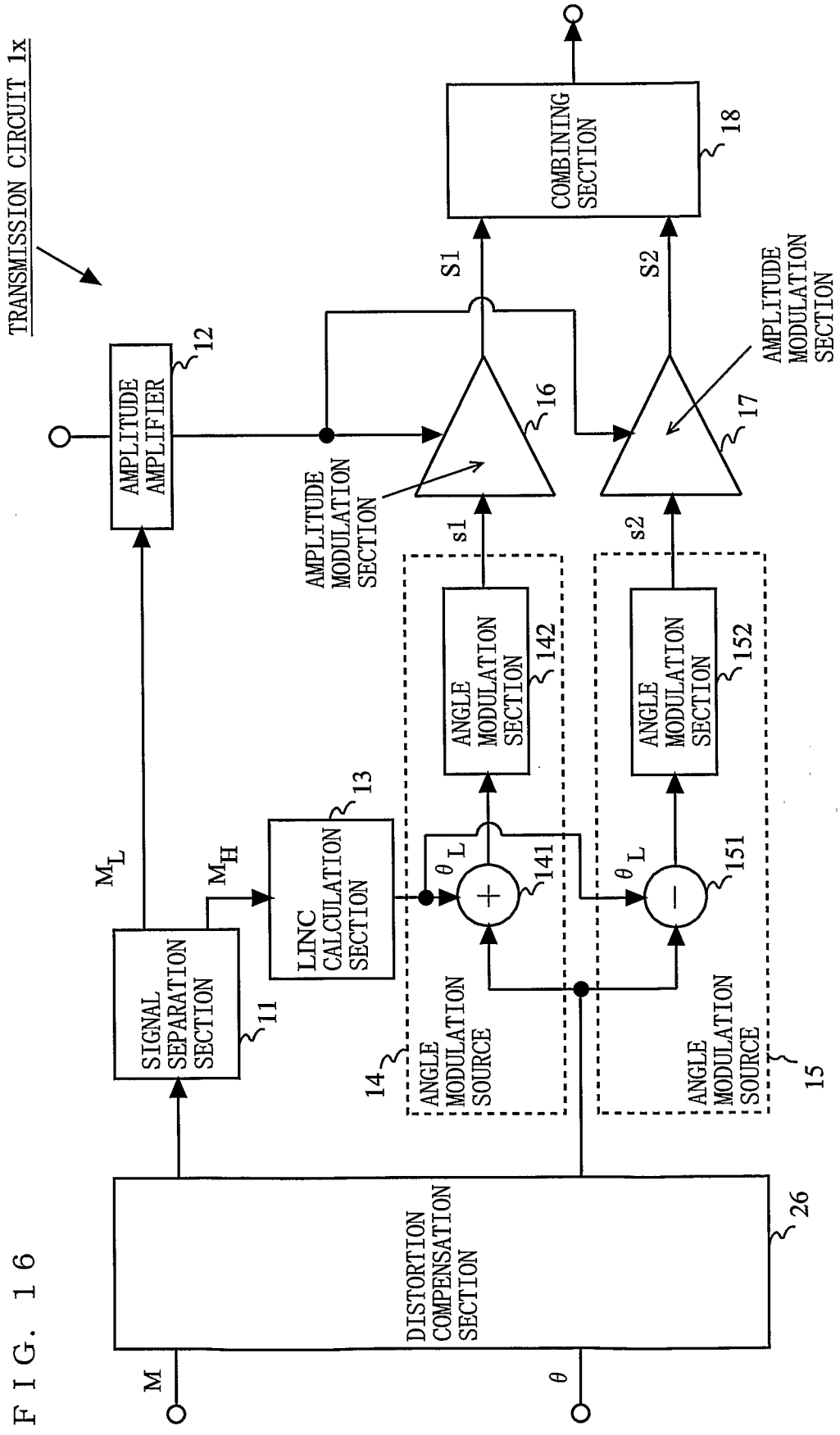

TRANSMISSION CIRCUIT 1x
AMPLITUDE AMPLIFIER
12
SIGNAL SEPARATION SECTION
11
LINC CALCULATION SECTION
13
ANGLE MODULATION SOURCE
14
ANGLE MODULATION SOURCE
15
ANGLE MODULATION SECTION
142
ANGLE MODULATION SECTION
152
AMPLITUDE MODULATION SECTION
AMPLITUDE MODULATION SECTION
16
17
COMBINING SECTION
18
DISTORTION COMPENSATION SECTION
26
M
θ
M_L
M_H
θ_L
θ_L
141
151
s1
s2
S1
S2

FIG. 16

F I G. 1 7 A

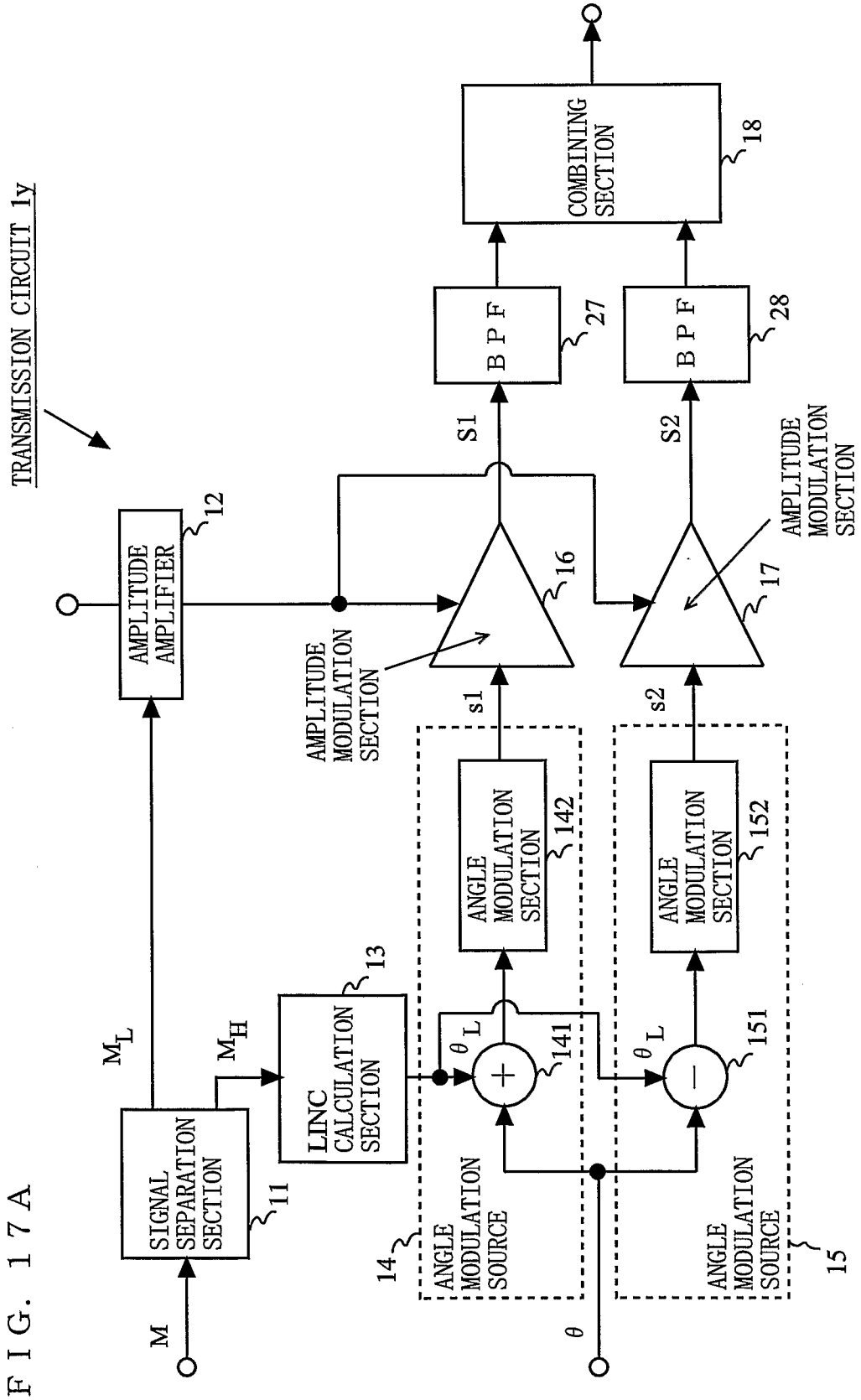

TRANSMISSION CIRCUIT 1y
M
SIGNAL SEPARATION SECTION
11
M_L
M_H
LINC CALCULATION SECTION
13
AMPLIFIER
12
ANGLE MODULATION SOURCE
14
ANGLE MODULATION SOURCE
15
θ
θ_L
141
ANGLE MODULATION SECTION
142
ANGLE MODULATION SECTION
152
θ_L
151
s1
s2
AMPLITUDE MODULATION SECTION
16
AMPLITUDE MODULATION SECTION
17
S1
S2
B P F
27
B P F
28
COMBINING SECTION
18

FIG. 17B

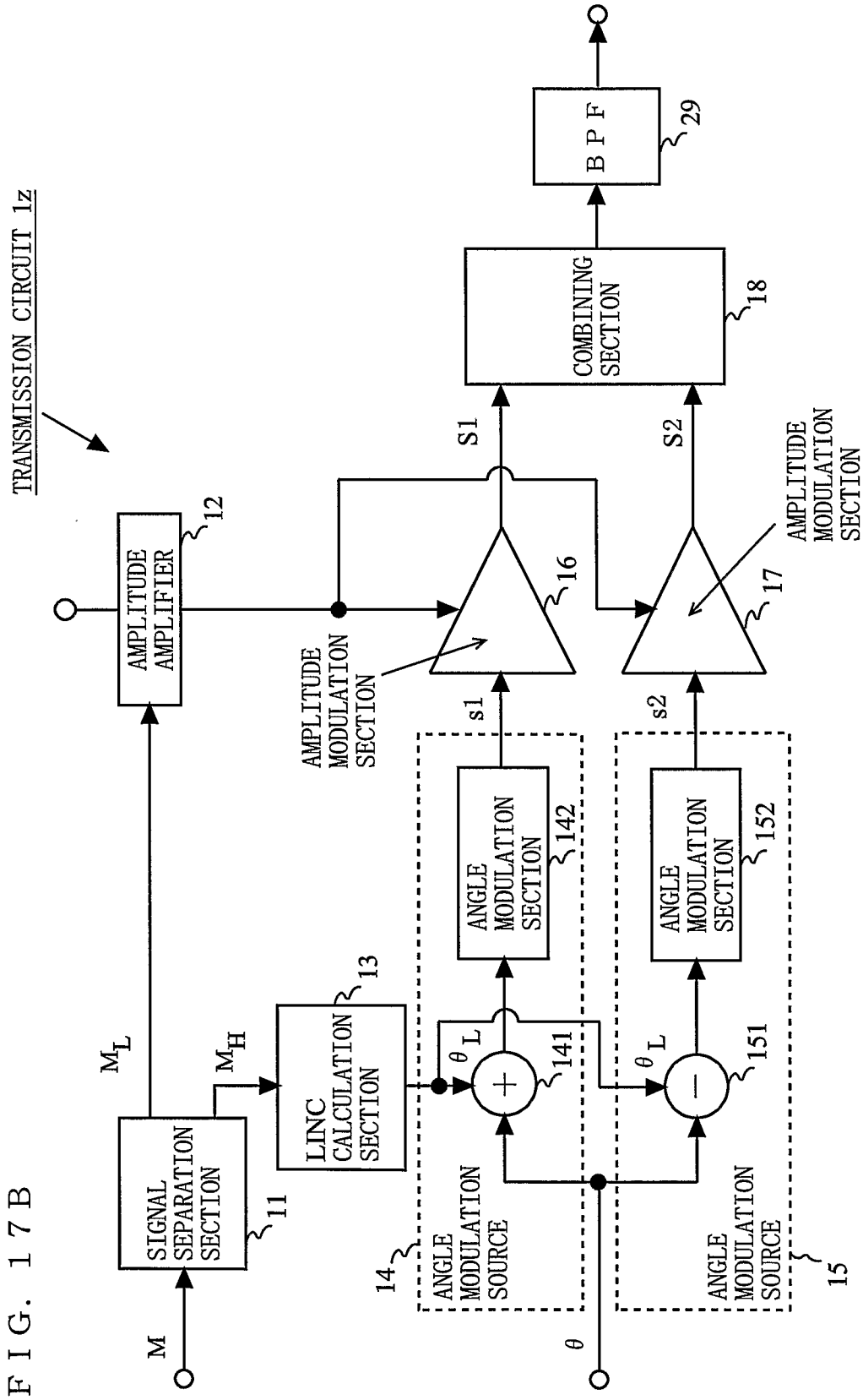
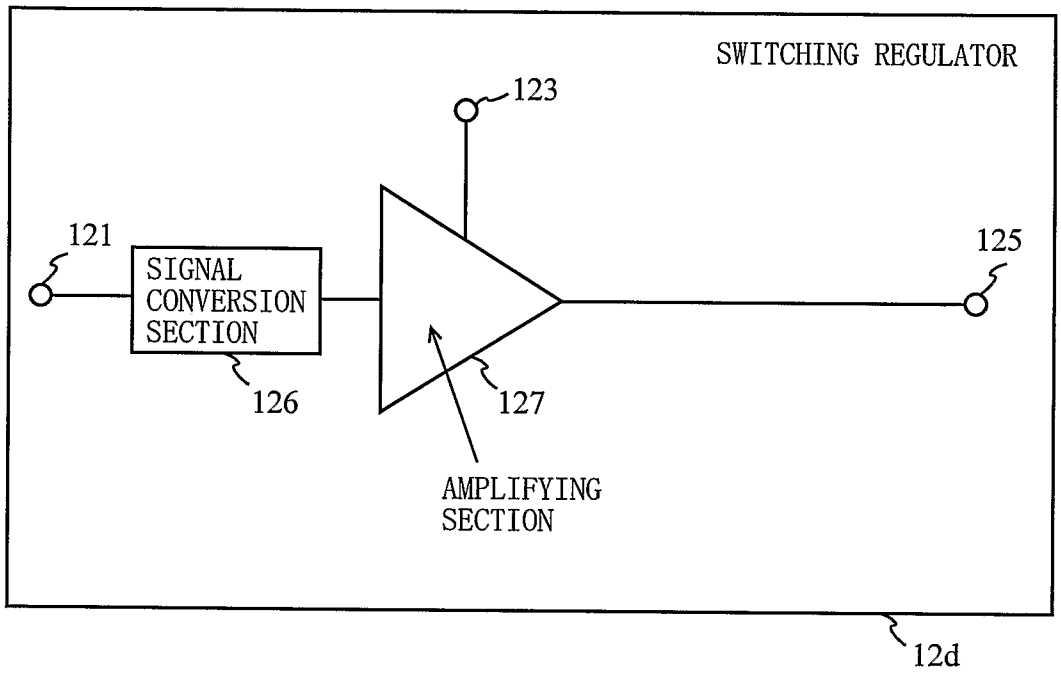

TRANSMISSION CIRCUIT 1z
M
SIGNAL SEPARATION SECTION
11
M_L
M_H
LINC CALCULATION SECTION
13
AMPLIFIER
12
AMPLITUDE MODULATION SECTION
ANGLE MODULATION SOURCE
14
ANGLE MODULATION SOURCE
15
θ
θ_L
141
θ_L
151
ANGLE MODULATION SECTION
142
ANGLE MODULATION SECTION
152
s1
s2
16
17
AMPLITUDE MODULATION SECTION
S1
S2
COMBINING SECTION
18
BPF
29

FIG. 17C


SWITCHING REGULATOR
123
121
SIGNAL CONVERSION SECTION
125
126
127
AMPLIFYING SECTION
12d

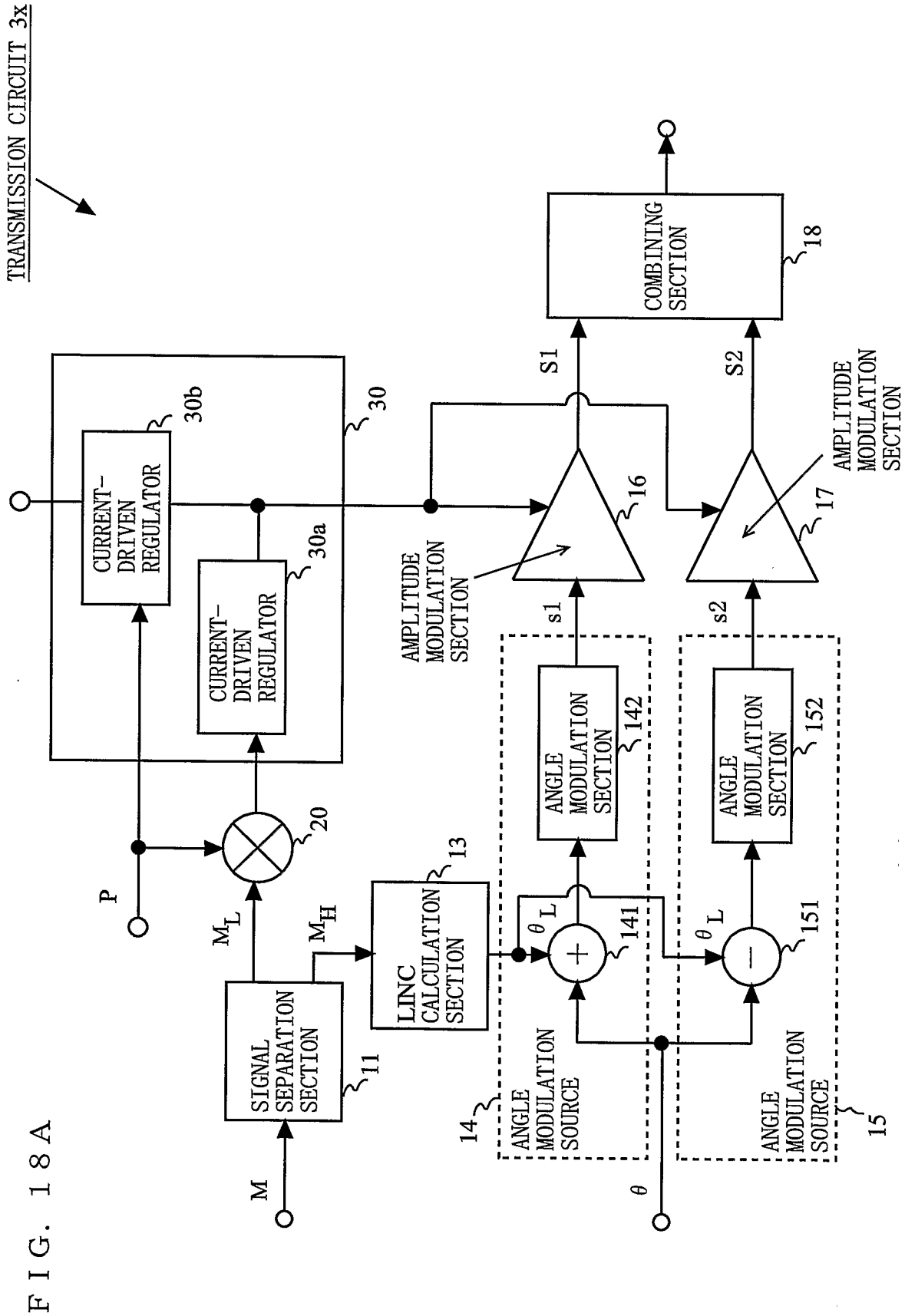

TRANSMISSION CIRCUIT 3x
SIGNAL SEPARATION SECTION
11
LINC CALCULATION SECTION
13
ANGLE MODULATION SOURCE
14
ANGLE MODULATION SOURCE
15
AMPLITUDE MODULATION SECTION
16
AMPLITUDE MODULATION SECTION
17
COMBINING SECTION
18
CURRENT-DRIVEN REGULATOR
30a
CURRENT-DRIVEN REGULATOR
30b
30
20
ANGLE MODULATION SECTION
142
ANGLE MODULATION SECTION
152
141
151
M
P
M_L
M_H
θ
θ_L
θ_L
s1
s2
S1
S2

FIG. 18A

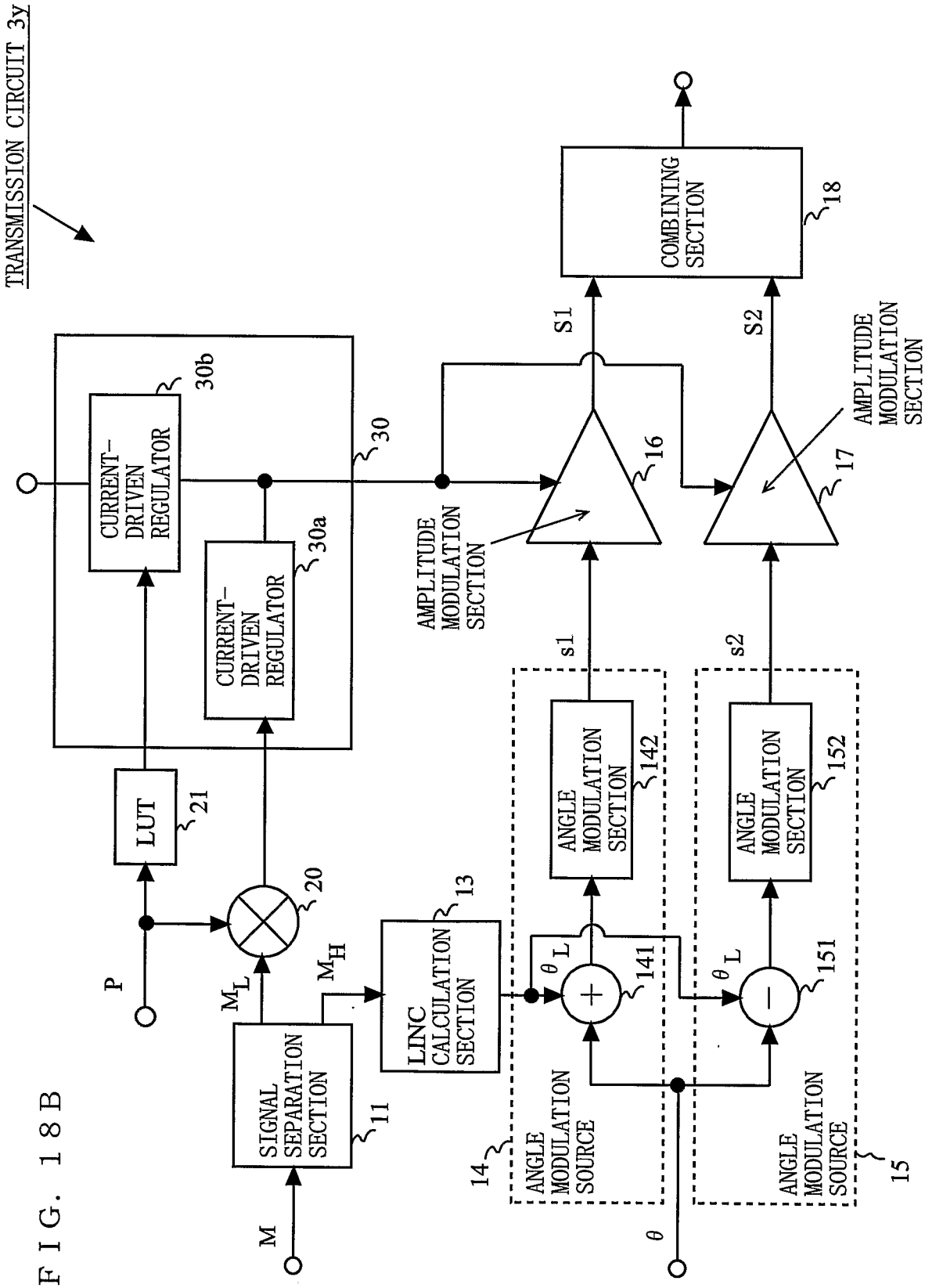

TRANSMISSION CIRCUIT 3y
M
SIGNAL SEPARATION SECTION
11
M_L
M_H
P
LUT
21
20
LINC CALCULATION SECTION
13
CURRENT-DRIVEN REGULATOR
30b
CURRENT-DRIVEN REGULATOR
30a
30
14
ANGLE MODULATION SOURCE
s1
ANGLE MODULATION SECTION
142
θ_L
141
AMPLITUDE MODULATION SECTION
16
S1
15
ANGLE MODULATION SOURCE
s2
ANGLE MODULATION SECTION
152
θ_L
151
AMPLITUDE MODULATION SECTION
17
S2
COMBINING SECTION
18
θ

FIG. 18B

FIG. 18C

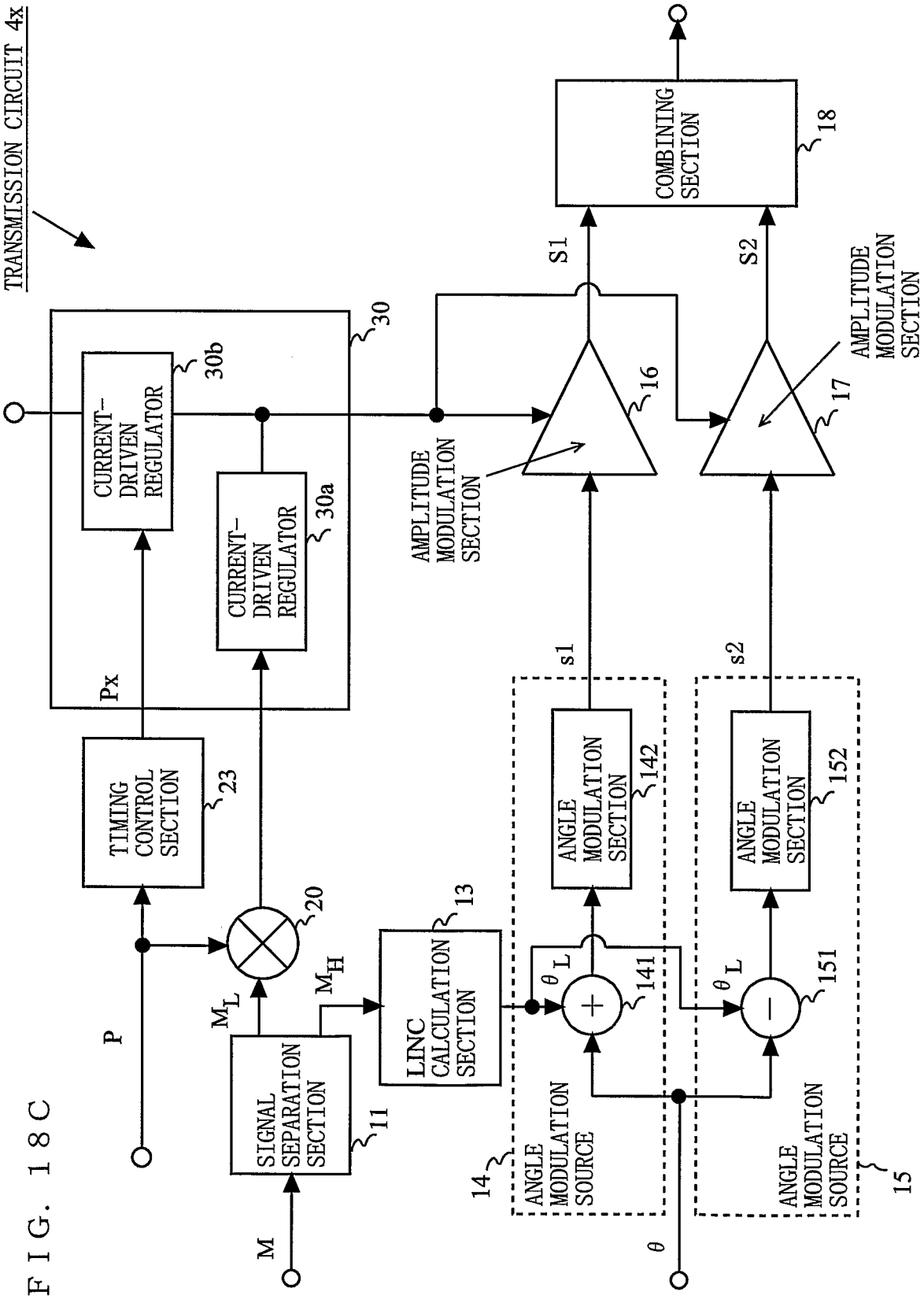

TRANSMISSION CIRCUIT 4x
30
CURRENT-DRIVEN REGULATOR
30b
CURRENT-DRIVEN REGULATOR
30a
Px
TIMING CONTROL SECTION
23
P
20
SIGNAL SEPARATION SECTION
11
M
M_L
M_H
LINC CALCULATION SECTION
13
14
ANGLE MODULATION SOURCE
θ
θ_L
141
ANGLE MODULATION SECTION
142
s1
AMPLITUDE MODULATION SECTION
16
S1
COMBINING SECTION
18
S2
AMPLITUDE MODULATION SECTION
17
s2
θ_L
151
ANGLE MODULATION SECTION
152
ANGLE MODULATION SOURCE
15

FIG. 19

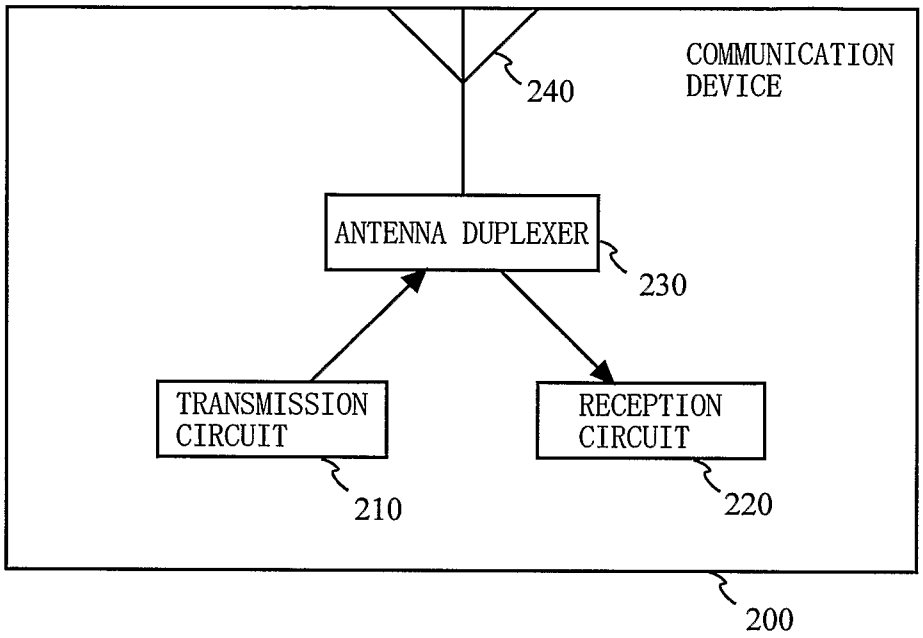

COMMUNICATION DEVICE
240
ANTENNA DUPLEXER
230
TRANSMISSION CIRCUIT
210
RECEPTION CIRCUIT
220
200

FIG. 20

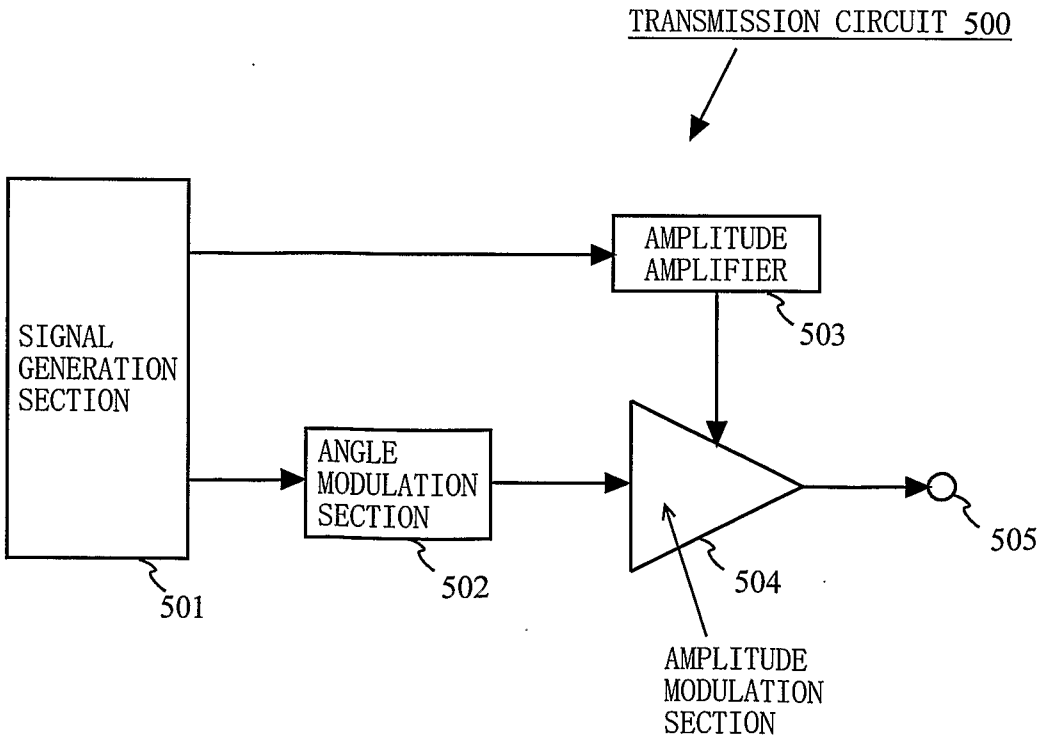

TRANSMISSION CIRCUIT 500
SIGNAL GENERATION SECTION
501
AMPLITUDE AMPLIFIER
503
ANGLE MODULATION SECTION
502
504
505
AMPLITUDE MODULATION SECTION

FIG. 21

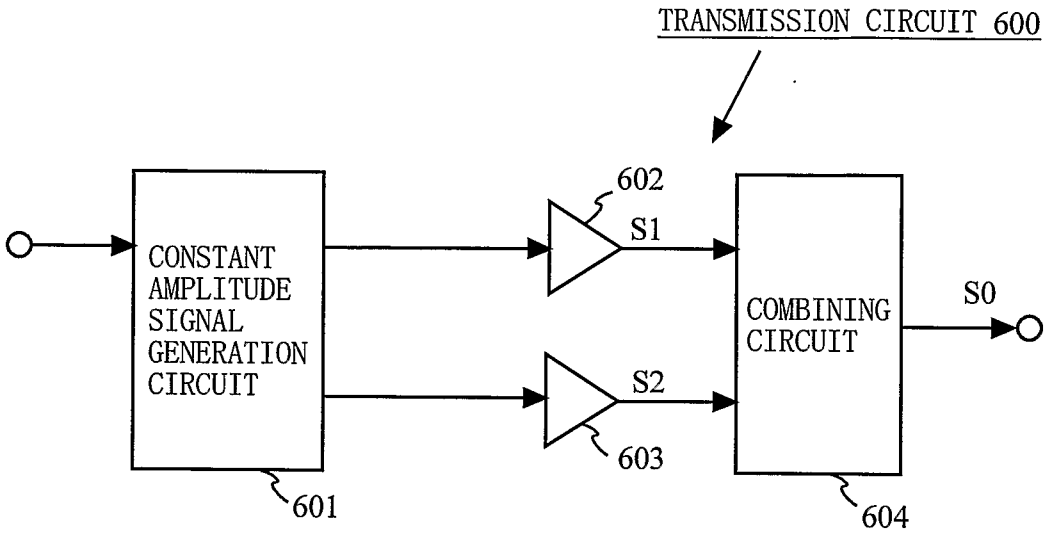

TRANSMISSION CIRCUIT 600
CONSTANT AMPLITUDE SIGNAL GENERATION CIRCUIT
601
602
S1
603
S2
COMBINING CIRCUIT
604
S0

FIG. 22

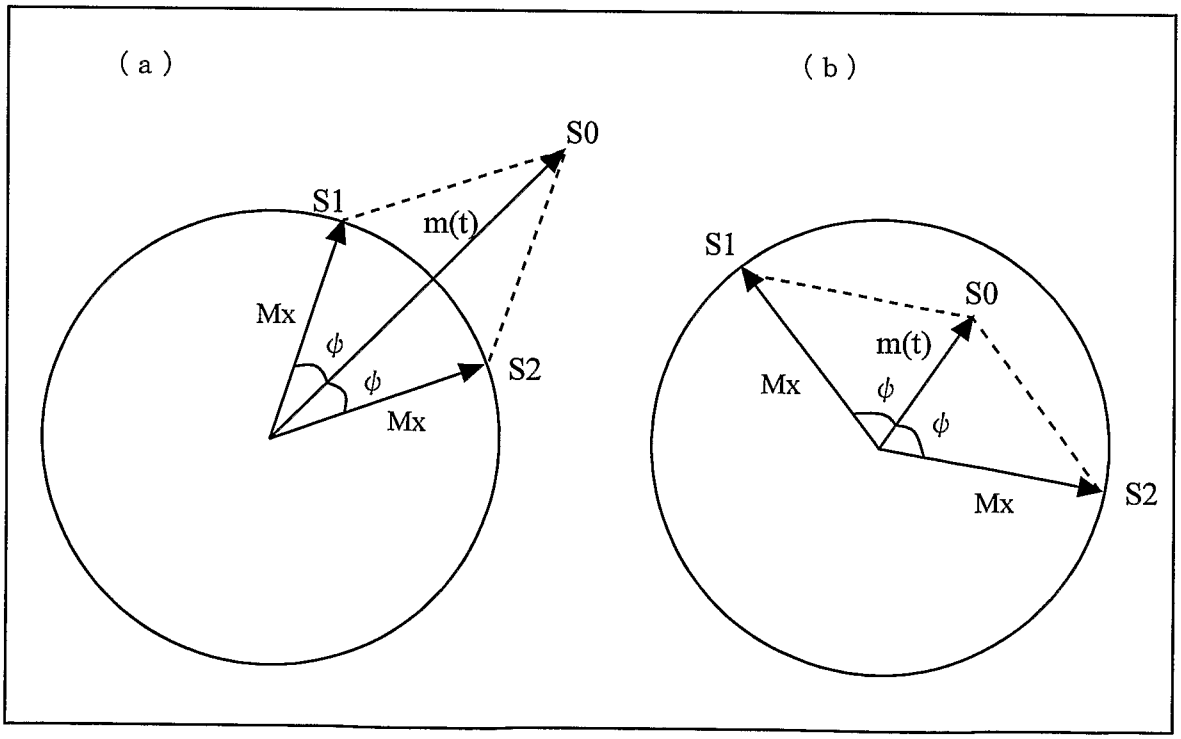
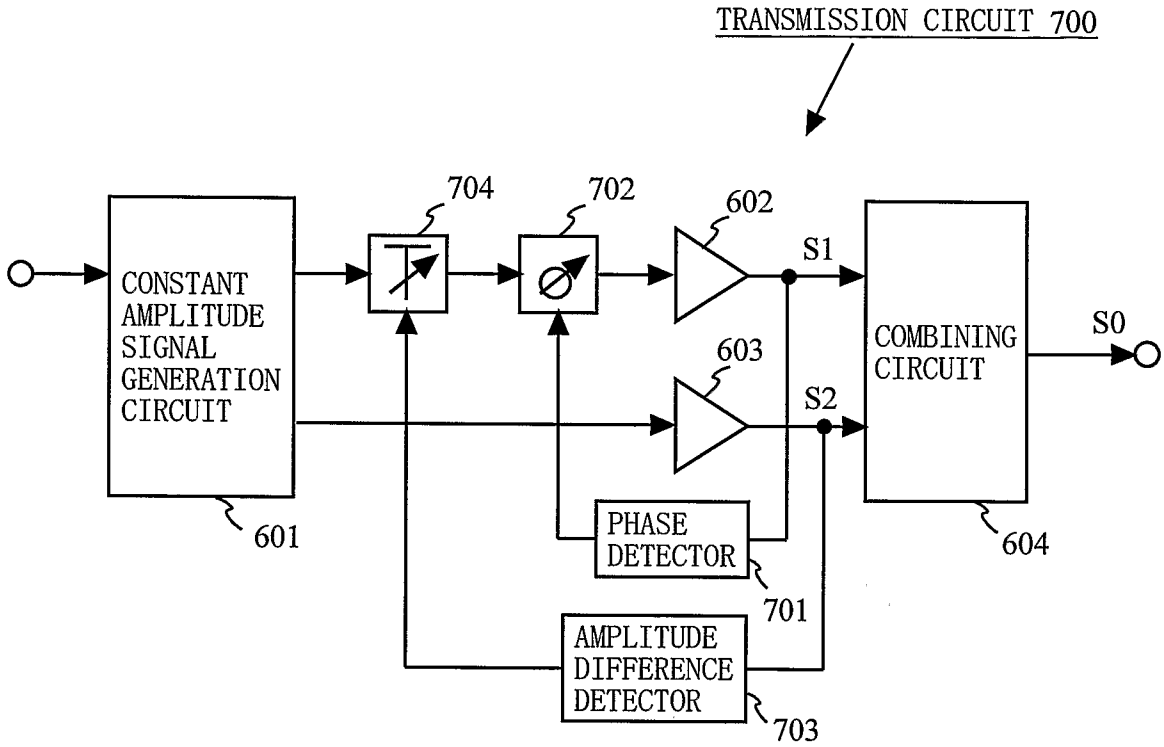

(a)
S0
S1
m(t)
Mx
φ
φ
S2
Mx
(b)
S1
S0
m(t)
Mx
φ
φ
Mx
S2

FIG. 23


TRANSMISSION CIRCUIT 700
CONSTANT AMPLITUDE SIGNAL GENERATION CIRCUIT
601
704
702
602
603
S1
S2
S0
COMBINING CIRCUIT
604
PHASE DETECTOR
701
AMPLITUDE DIFFERENCE DETECTOR
703

INTERNATIONAL SEARCH REPORT

International application No
PCT/JP2008/051904

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04L27/36 H03F1/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04L, H03F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the International search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 2005/164660 A1 (MATSUURA TORU [JP] ET AL) 28 July 2005 (2005-07-28) figures 1-4,7 abstract page 6, paragraph 91 - page 7, paragraph 94 page 7, paragraph 98 - paragraph 99	1-3,6,7, 11,12 8-10
A	JP 2005 079855 A (SUMITOMO ELECTRIC INDUSTRIES) 24 March 2005 (2005-03-24) page 5, paragraph 18 - paragraph 24	1-12
P,X	DE 10 2006 006875 B3 (REMBOLD BERNHARD [DE]) 3 May 2007 (2007-05-03) the whole document	1-12

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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"&" document member of the same patent family

Date of the actual completion of the International search	Date of mailing of the International search report
30 June 2008	08/07/2008

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Schiffer, Andrea

INTERNATIONAL SEARCH REPORT

International application No
PCT/JP2008/051904

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2006/118318 A (MATSUSHITA ELECTRIC IND CO LTD [JP]; MATSUURA TORU; ADACHI HISASHI) 9 November 2006 (2006-11-09) figures 20,22A	8-10
A	COX D C:. "LINEAR AMPLIFICATION WITH NONLINEAR COMPONENTS" IEEE INTERNATIONAL SYMPOSIUM ON CIRCUITS AND SYSTEMS, XX, XX, 22 April 1974 (1974-04-22), pages 157-161, XP000997101 the whole document	1-12

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/JP2008/051904

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