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(54) Abstract Title
Directional coupler with variable coupling

(57) A directional coupler 23 comprises a main strip line 231, a sub strip line 232 and a terminating circuit 24 for selectively terminating, in response to a control signal S3, one of a plurality of different positions of the sub strip line so as to change the coupling length of the sub strip line and thus the degree of coupling between the main and sub strip lines. Preferably the terminating circuit comprises a plurality of series circuits, connected between the different positions of the sub strip and a grounding terminal, which consist of a switch 241, 242, opened or closed in response to the control signal, and a terminating resistor 246, 247. The directional coupler may be provided in a power transmission output control apparatus 10 of a mobile 'phone which is operable in a 'phone power down mode (standby), where the sub strip is terminated at its end 242, and in a power up mode (active use) where the sub strip is terminated half way along 241. The variable coupling can therefore be used for accounting for the frequency variation in the power supplied to the 'phone antenna 37.

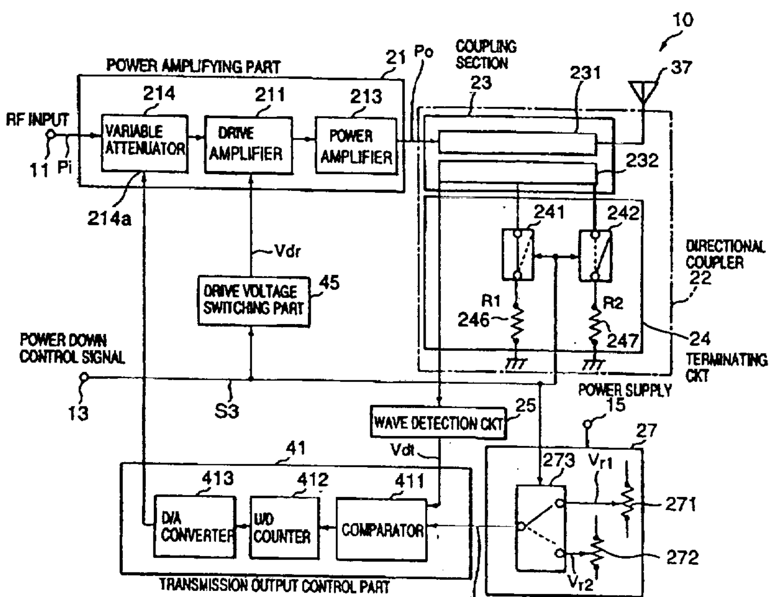

FIG. 3

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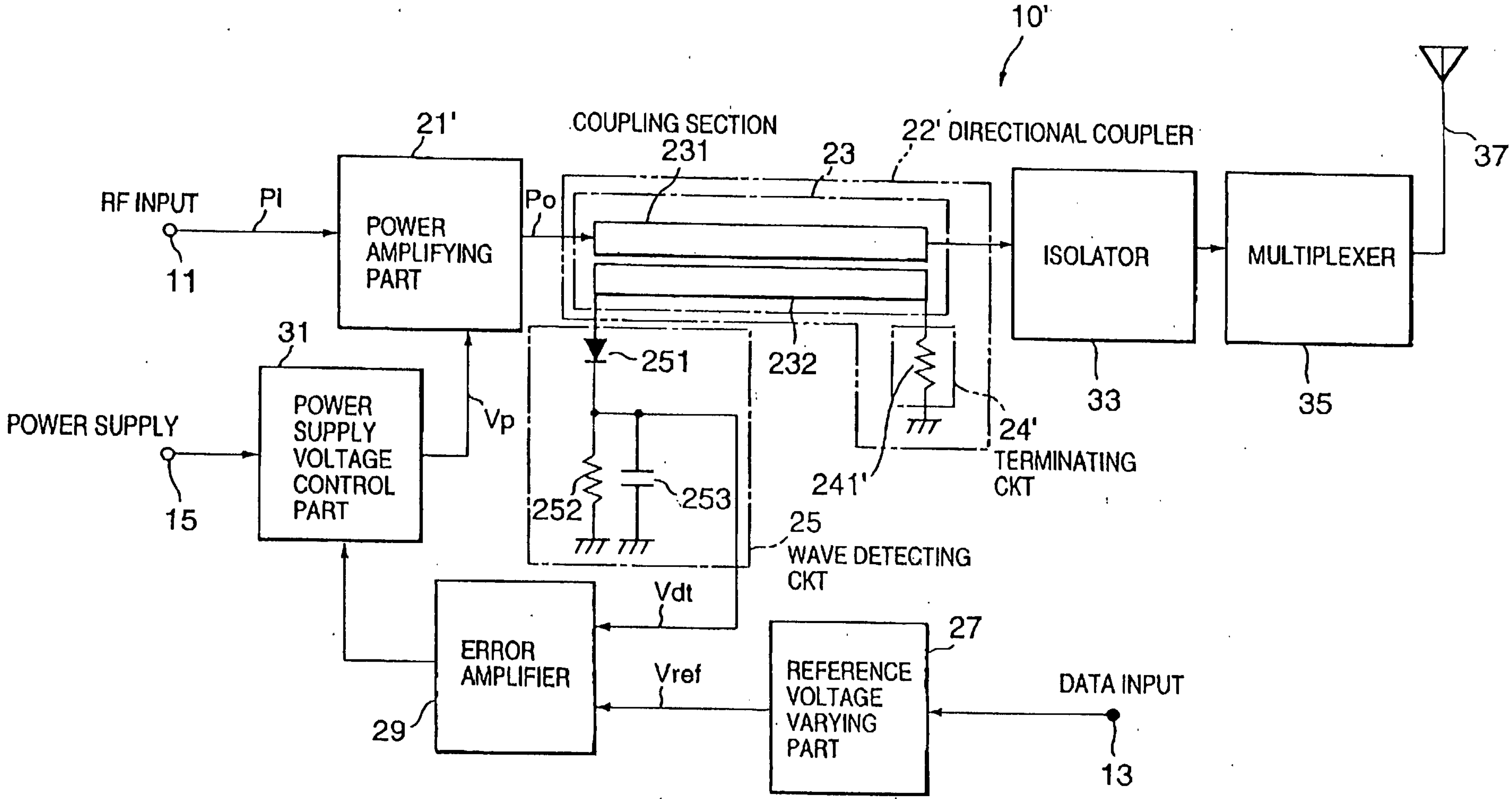

FIG. 1 PRIOR ART

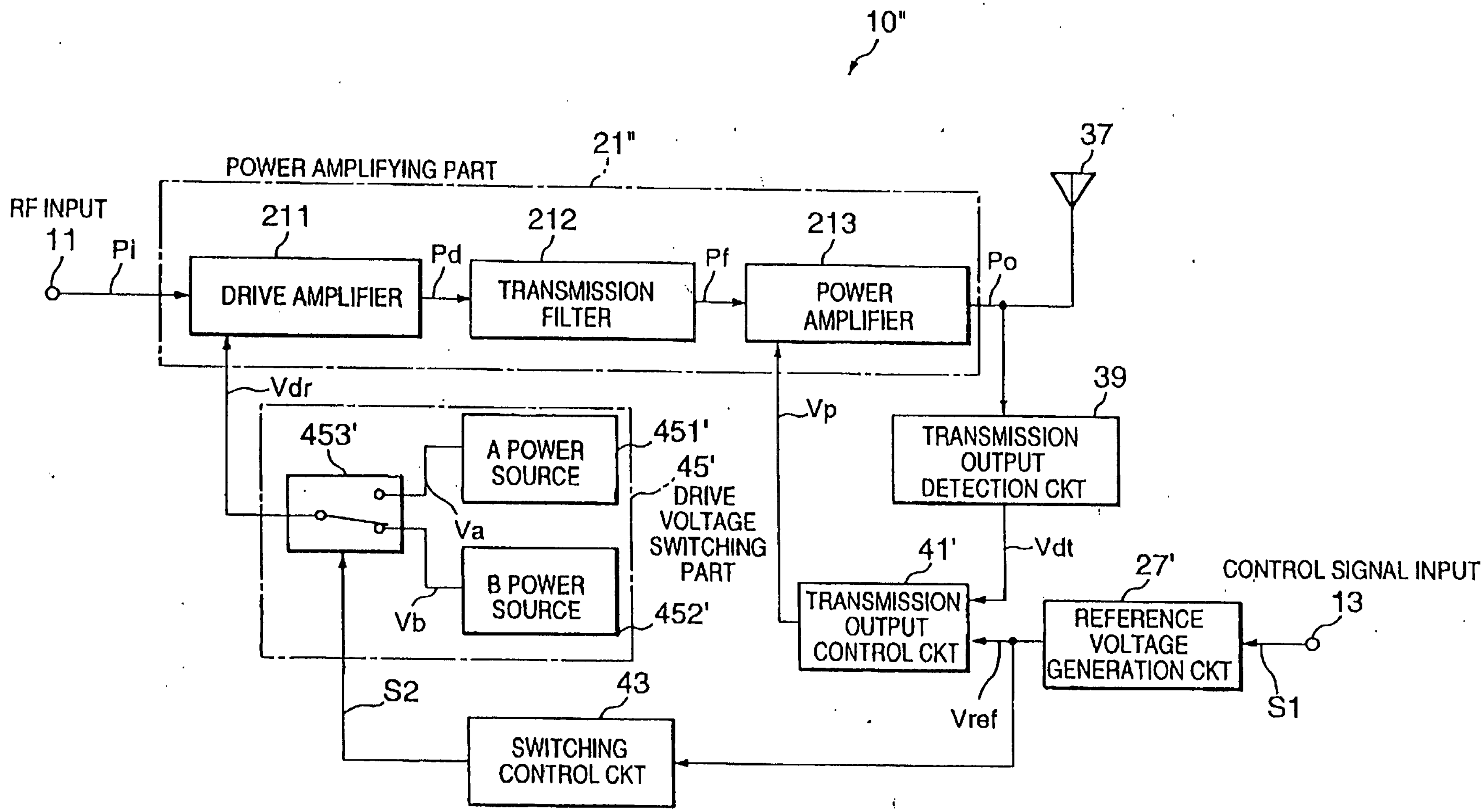

FIG. 2 PRIOR ART

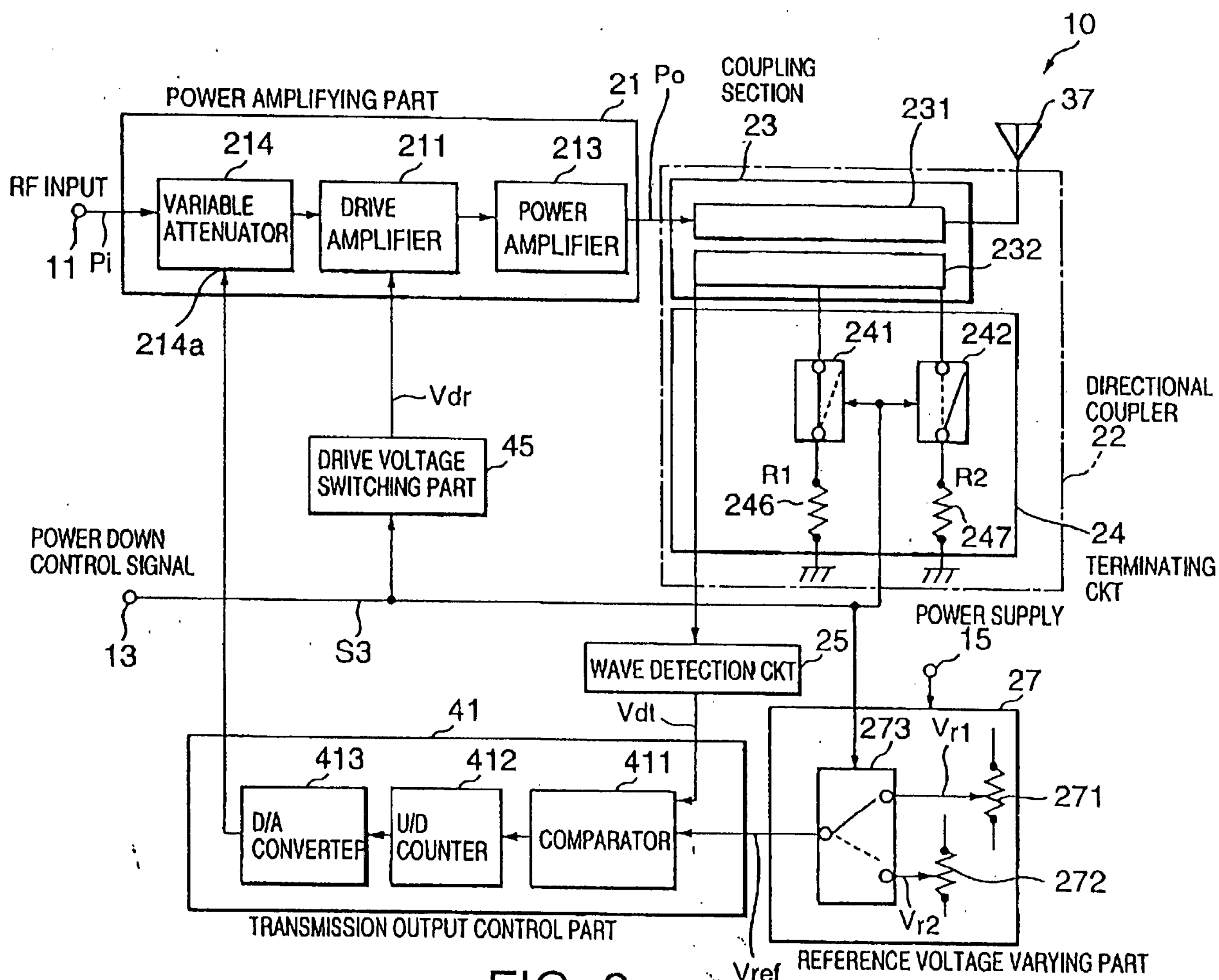
10
37
POWER AMPLIFYING PART
21
Po
COUPLING SECTION
23
231
232
RF INPUT
11
Pi
214
VARIABLE ATTENUATOR
211
DRIVE AMPLIFIER
213
POWER AMPLIFIER
214a
241
242
Vdr
DRIVE VOLTAGE SWITCHING PART
45
DIRECTIONAL COUPLER
22
R1
246
R2
247
24
TERMINATING CKT
POWER DOWN CONTROL SIGNAL
13
S3
POWER SUPPLY
15
WAVE DETECTION CKT
25
27
41
Vdt
273
Vr1
413
D/A CONVERTER
412
U/D COUNTER
411
COMPARATOR
271
272
Vr2
TRANSMISSION OUTPUT CONTROL PART
Vref
REFERENCE VOLTAGE VARYING PART

FIG. 3

TRANSMISSION OUTPUT CONTROL APPARATUS HAVING A DIRECTIONAL COUPLER WITH A VARIABLE COUPLING LENGTH

Background of the Invention:

This invention relates to a transmission output control apparatus and, more particularly, to a transmission output control circuit for use in a radio telephone set for a simple portable telephone system such as a personal handyphone system (PHS) in Japan.

Various transmission output control apparatuses of the type are already known. By way of example, Japanese Unexamined Patent Publication of Tokkai No. Show. 61-121,537 or JP-A 62-121537 discloses an electric power control circuit having no power deviation in a wide frequency range by switching the reference voltage level according to the change of the output frequency of a power amplifying part. In the manner which will later be described in conjunction with Fig. 1, according to JP-A 62-121537, a partial electric power amplified by a power amplifying part is detected by a directional coupler consisting of strip lines and a terminating resistor and then converted into the DC voltage by a wave detecting circuit consisting of a diode, a resistor and a capacitor. At the same time a reference voltage varying part obtains the data on the frequency information through a data terminal and sends a selected reference voltage. An error amplifier compares the DC voltage sent from the wave detecting part with the selected reference voltage sent from the reference voltage varying part and amplifies the obtained error voltage to apply it to a power supply voltage control part. The power supply voltage control part controls the power supply voltage given from a power supply terminal and varies the output of the power amplifying part to reduce the power deviation with a band.

With this structure, it is possible to vary the output of the power amplifying part to reduce the power deviation within a band. That is, inasmuch as the wave detecting circuit has a frequency characteristic, it is impossible to avoid the power deviation if the reference voltage is fixed. In order to remove this defect, the reference voltage varying part changes the reference voltage in response to a control signal indicative of frequency information. As a result, it is possible to make the high-frequency output level power down step-by-step. However, in this case, the electric power control circuit according to JP-A 62-121537 is disadvantageous in that a range of the transmission output is limited.

On the other hand, in order to resolve this problem, techniques, which can easily control a level of the transmission output at a wide range, are disclosed, for example, in Japanese Unexamined Patent Publication of Tokkai No. Hei 9-148,945 or JP-A 9-148945 which will later be described.

In addition, in JP-A 62-121537, the directional coupler comprises a coupling section and a terminating circuit. The coupling section consists of a main or primary strip line and a sub or secondary strip line which are arranged in parallel to each other with a space left therebetween. The terminating circuit consists of the terminating resistor connected to an end of the sub strip line. That is, the directional coupler has only one degree of coupling because the sub strip line has a fixed coupling length.

The afore-mentioned JP-A 9-148945 discloses a transmission output control system having a wide transmission output change range. In the manner which will later be described in conjunction with Fig. 2, according to JP-A 9-148945, a power amplifier constitutes an automatic output control amplification circuit together with a transmission output detection circuit, a transmission output control circuit, and a reference voltage generation circuit. The reference voltage generation circuit generates a selected reference voltage out of a plurality of reference voltages. The power amplifier generates a transmission output corresponding to the selected reference voltage. A switching control circuit selects an output voltage a first power source or an output voltage of a second power source as a supply voltage (drive voltage) of drive amplifier, which drives the power amplifier, based on the selected reference voltage. When the output voltage of the second power source is selected as the supply voltage, the gain of the drive amplifier is reduced, and the required gain of the power amplifier is raised. Therefore, leakage to the output terminal of a high frequency signal at the time of inactivity of the power amplifier is reduced, and the transmission output range is extended. JP-A 9-148945 discloses no directional coupler.

With this structure, the drive voltage for the drive amplifier is changed and amplification degree of the power amplifier is changed. Accordingly, it is possible to carry out a level control by combining both of the changing ranges. Specifically, a range of the amplification degree of the power amplifier is applicable with respect to two-stage drive voltages of a high drive voltage and a low drive voltage in a drive voltage switching part for the drive amplifier.

However, even though the amplification degree of the wide range is obtained, the transmission output detection circuit (or the wave detecting circuit) for detecting a level of the transmission output has a limited dynamic range between 15dB and 20dB. Accordingly, in a case where a power down function beyond 20dB is required, structure for setting to a power down output having a predetermined value is adopted by giving a fixed bias voltage to a voltage controlled variable attenuator composed of a pin diode and so on in a RF stage of a transmission system and by lowering a gain of the transmission system by means of removing the drive amplifier from the transmission system by cutting down a power supply for the drive amplifier.

The transmission output control system according to JP-A 9-148945 is disadvantageous in that it is impossible to obtain a stable transmission output in the case where the power down function beyond 20dB is required. This is because the automatic output control amplification circuit, which feeds an error of the transmission output with respect to the reference voltage back to a power amplifying part, is put into an off state in a substantial power down state and it is therefore impossible to absorb variation in a gain of the amplifier in the transmission system due to fluctuations of ambient temperature. In addition, a circuit configuration is complicated in a case of carrying out correction corresponding to the fluctuation of ambient temperature and it is therefore impossible to avoid a large size.

Japanese Unexamined Patent Publication of Tokkai No. Hei 5-268,139 or JP-A 5-268139 discloses a power amplifier circuit for a portable telephone formed inexpensively with simple configuration. According to JP-A 5-268139, the power amplifier circuit consists of a main body and an adaptor. The main body is provided with an amplifier means for amplifying a sent high frequency signal, a power detection means for detecting an output level of the amplifier means, an output control means for keeping an output level of the amplifier means at a prescribed level based on the detection output of the power detection means, an output variable means for revising the kept prescribed level, and a connection detection means for detecting whether or not the adaptor is connected to the main body. The adaptor is provided with a linear amplifier for amplifying an output of the amplifier means when the adaptor is connected to the main body. When the adaptor is connected to the main body by a connection detection means, the output variable stage number by an output variable means is changed from that when the adoptor is not connected. JP-A 5-268139 discloses no direction coupler.

Japanese Unexamined Patent Publication of Tokkai No. Hei 6-197,076 or JP-A 6-197076 discloses a digital radio telephone set which is capable of controlling a power level of a transmission output with simple circuit configuration. According to JP-A 6-197076, a connection means of the TDD/TDMA system digital radio telephone set connects part of a transmission output to a reception circuit at transmission in interlocking with a changeover means selectively connecting a transmission circuit and a reception circuit to an antenna. A feedback circuit feeds back an electric field strength level received by the reception circuit with respect to the transmission output at that time to a transmission output control circuit of the transmission circuit.

JP-A 6-197076 may disclose a coupler or a directional coupler. However, JP-A 6-197076 neither discloses nor teaches detailed structure in the directional coupler.

Japanese Unexamined Patent Publication of Tokkai No. Hei 8-274,559 or JP-A 8-274559 discloses an output power controller with a wide temperature compensation range and capable of executing power control satisfactorily. According to JP-A 8-274559, the output power controller is equipped with an isolator to which a transmission signal amplified by a power amplifier is inputted via a transmission line connected to the output side of the power amplifier and which passes only a progressive wave component, and a detection circuit which forms the detection signal of an actual output power by fetching a part of an output power from the input point of the isolator and comprises the input stage of a feedback control system. Also, it is equipped with a reactance matching element which cancels parasitic reactance in the fetch part of the detection circuit and connected to the input point to the isolator.

JP-A 8-274559 discloses a directional coupler in prior art thereof. The directional coupler disclosed in JP-A 8-274559 is similar in structure and operation to that illustrated in JP-A 62-121537 and has therefore only one degree of coupling.

Japanese Unexamined Patent Publication of Tokkai No. Hei 10-145,160 or JP-A 10-145160 discloses an automatic output control circuit which is capable of widening a control range of an output level and of decreasing temperature fluctuation in the output level. According to JP-A 10-145160, an input signal is amplified by first through third amplifiers and given to a main transmission line of first and second direction couplers. A first branching filter branches this output signal to a first sub-transmission line at a branching gain of about -15(dB), a second branching filter branches the signal to a second sub-transmission line and the resulting signal is amplified by a fourth amplifier, and a synthesis branching gain is about 0(dB). An operational amplifier controls the gain of the second and the third amplifiers, depending on a difference between a reference voltage and an output detection voltage. In the usual mode where a mode switching signal is at 'H', only a first detection diode is biased forward, a branching signal of the first branching filter section is detected by a first detection section and the detected voltage is produced. Furthermore, in the low output mode where the mode switching signal is at 'L', the gain of the first amplifier is selected to be smaller than that of the usual mode by about 15(dB), and only a second detection diode is biased forward, a branching signal of a second branching filter section being detected by a second detection section.

As described above, JP-A 10-145160 discloses a combination of the first and the second directional couplers. The first and the second directional couplers comprise the main transmission line in common. The first directional coupler comprises the first sub-transmission line and a first sub-terminating resistor connected to an end of the first sub-transmission line. The second directional coupler comprises the second sub-transmission line and a second terminating resistor connected to an end of the second sub-transmission line. Accordingly, each of the first and the second directional couplers has only one degree of coupling. This is because each of the first and the second sub-transmission lines has a fixed coupling length.

Japanese Unexamined Patent Publication of Tokkai No. Hei 5-152,977 or JP-A 5-152977 discloses a transmission output control circuit which is capable of use for a TDMA-type radio transmitter, etc, and stably controlling a transmission output burst wave with high accuracy over a wide output area. According to JP-A 5-152977, the transmission output control circuit is provided with a closed loop system for fetching a part of transmitting output by a directional coupler, detecting it by a detector, comparing it with a reference voltage and controlling a power amplifier, and an open loop system for controlling a drive amplifier pre-positioned in the power amplifier. By combining the control of both loops, the wide-area and multistage control of the transmission output is realized.

JP-A 5-152977 discloses a directional coupler which is similar in structure and operation to that illustrated in JP-A 62-121537 and has therefore only one degree of coupling.

Japanese Unexamined Utility Model Publication of Jikkai No. Show 63-102,303 or JP-U 63-102303 discloses a directional coupler which is simple in structure without using a complicated high-frequency switch. According to JP-U 63-102303, the directional coupler comprises a small-power strip line directional coupler having a narrow strip space and a large-power strip line directional coupler, opposite to the small-power strip line directional coupler, having a wider strip space than that of the small-power strip line directional coupler.

In other words, JP-U 63-102303 discloses the directional coupler comprising a main strip line, first and second sub strip lines, and first and second terminating resistors which are connected to ends of the first and the second sub strip lines, respectively. Each of the first and the second sub strip lines had a fixed coupling length. Accordingly, the directional coupler according to JP-U 63-102303 may have two degrees of coupling. However, the directional coupler according to JP-U 63-102303 is complicated in structure because the directional coupler comprises two sub strip lines.

Japanese Unexamined Utility Model Publication of Jikkai No. Hei 5-41,206 or JP-U 5-41206 discloses a high general-purpose directional coupler comprising a main line and sub-lines which are formed on a printed wiring board, that is small, is mounted on the same printed wiring board, and is capable of using a plurality of frequency bands. According to JP-U 5-41206, the directional coupler comprises a main line, two sub-lines which are arranged in parallel to the main line at both side thereof and which have different line lengths, and switching means for selectively switching outputs of the two sub-lines. In addition, a plurality of sub-lines may be disposed on the same straight line.

As described above, the directional coupler according to JP-U 5-41206 comprises the main line and the plurality of sub-lines. Accordingly, the directional coupler may change a coupling length in a case where the plurality of sub-lines are disposed on the sama straight line. However, the directional coupler according to JP-U 5-41206 is complicated in structure because the directional coupler comprises the plurality of sub-lines.

Japanese Unexamined Patent Publication of Tokkai No. Hei 7-336,243 or JP-A 7-336243 discloses a transmission output controller which is capable of reducing the current consumption by conducting power control during continuous transmission specific to the CDMA system over a wide dynamic range. According to JP-A 7-336243, fluctuation in the amplified component of digital orthogonal modulation is eliminated by low pass filters and high speed rising/falling control of a burst wave is conducted not through the low pass filter with a changeover switch, then the power control during continuous transmission is conducted over a wide dynamic range. Since a power amplifier is operated with a constant gain even in the presence of fluctuation in the power supply voltage, fluctuation in frequency and the revision of an operation bias condition or the like, the current consumption is reduced.

JP-A 7-336243 discloses a directional coupler which is similar in structure and operation to that illustrated in JP-A 62-121537 and has therefore only one degree of coupling.

Another example is disclosed in United States Patent No. 5,640,691 issued to Davis et al., under the title of "POWER CONTROLLER FOR RF TRANSMITTERS." According to Davis et al., an RF transmitter network for cellular telephone systems is provided. The network includes power amplifier circuitry which is coupled to a closed loop control system to provide a controllable RF amplitude envelope for the output power of the amplifier circuitry over a dynamic range of between about 5 milliwatts and about 3200 milliwatts.

Davis et al. may disclose a directional coupler. However, Davis et al. neither discloses nor teaches detailed structure in the directional coupler.

Japanese Unexamined Patent Publication of Tokkai No. Hei 10-150,429 or JP-A 10-150429 discloses a transmission circuit in which current consumption is reduced in response to a transmission output with a wide dynamic range. According to JP-A 10-150429, the transmission circuit has an orthogonal modulator, a gain control amplifier, an up-mixer, a driver amplifier, a power amplifier and an antenna and is configured so as to generate a transmission output of a wide range. In this case, there are provided a first switch that bypasses an input signal of the driver amplifier, a second switch that bypasses an input signal of the power amplifier and a controller that applies on/off control to a power supply of the drive amplifier and the power amplifier to generate a control signal for the gain control amplifier, the first switch and the second switch. A current at a low transmission output is reduced by conducting the gain control of the gain control amplifier depending on the transmission output, bypass control of the input signal to the power amplifier and the driver amplifier, and power on/off control of the power amplifier and the driver amplifier. JP-A 10-150429 discloses no directional coupler.

Summary of the Invention:

It is therefore an object of a preferred embodiment of this invention to provide a transmission output control apparatus, which is capable of obtaining a stabilized transmission output in a case where a wide power-down function is required.

It is another object of the preferred embodiment of this invention to provide a directional coupler, which is capable of changing a degree of coupling while simple in structure.

Other objects of the preferred embodiment of this invention will become clear as the description proceeds.

According to an aspect of this invention, a transmission output control apparatus comprises a power amplifying part, supplied with an input radio frequency signal, a transmission output control signal, and a drive voltage, for amplifying the input radio frequency signal in response to the transmission output control signal and the drive voltage to produce a transmission output signal. Connected to the power amplifying part and supplied with a control signal, a directional coupler extracts, in response to the control signal, a part of the transmission output signal as an extracted signal. The directional coupler comprises a coupling section and a terminating circuit connected to the coupling section for terminating the coupling section. The coupling section comprises a main strip line and a sub strip line which are arranged in parallel to each other. The terminating circuit is connected to a plurality of different positions of the sub strip line. The terminating circuit selectively terminates one of the different positions of the sub strip line in response to the control signal. Connected to the directional coupler, a wave detecting circuit detects the extracted signal to produce a detected DC voltage. A reference voltage generating arrangement generates a reference voltage. Connected to the power amplifying part, the wave detecting circuit, and the reference voltage generating arrangement, a transmission output control part compares the detected DC voltage with the reference voltage to supply the transmission output control signal to the power amplifying part. Connected to the power amplifying part and supplied with the control signal, a drive voltage switching part supplies the power amplifying part with the drive voltage in response to the control signal.

According to a second aspect of this invention, a directional coupler comprises a coupling section comprising a main strip line and a sub strip line which are arranged in parallel to each other. A terminating circuit selectively terminates one of a plurality of different positions of the sub strip line in response to a control signal, thereby changing degree of coupling of the directional coupler by changing a coupling length of the sub strip line.

Preferred features of the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:-

Fig. 1 is a block diagram of a first conventional transmission output control apparatus;

Fig. 2 is a block diagram of a second conventional transmission output control apparatus; and,

Fig. 3 is a block diagram of a transmission output control apparatus according to a preferred embodiment of this invention.

Description of the Preferred Embodiment:

Referring to Fig. 1, a first conventional transmission output control apparatus 10' will be described at first in order to facilitate an understanding of the present invention. The illustrated transmission output circuit is disclosed in the above-mentioned JP-A 61-121537.

The illustrated transmission output control apparatus 10' has a radio frequency (RF) input terminal 11, a data (control signal) input terminal 13, and a power supply terminal 15. The transmission output control apparatus 10' comprises a power amplifying part 21', a directional coupler 22' comprising a coupling section 23 and a terminating circuit 24', a wave detecting circuit 25, a reference voltage varying part 27, an error amplifier 29, a power supply voltage control part 31, an isolator 33, a multiplexer 35, and an antenna 37.

The power amplifying part 21' is connected to the radio frequency input terminal 11 and the power supply voltage control part 31 . The power amplifying part 21' is supplied from the radio frequency input terminal 11 and the power supply voltage control part 31 with an input radio frequency signal Pi and a controlled power supply voltage Vp in the manner which will later be described. The power amplifying part 21' amplifies the radio frequency input signal on the basis of the controlled power supply voltage to produce an amplified radio frequency signal as a transmission output signal Po. The transmission output signal Po is supplied to the directional coupler 22'.

As mentioned before, the directional coupler 22' comprises the coupling section 23 and the terminating circuit 24'. The coupling section 23 consists of a main strip line 231 and a sub strip line 232. The main strip line 231 is called a primary strip line while the sub strip line 232 is called a secondary strip line or a coupling strip line. The main strip line 231 and the sub strip line 232 are formed on a printed wiring board (not shown). In addition, the sub strip line 232 is arranged in parallel to the main strip line 231 at one side with a space left therebetween. The sub strip line 232 has an end connected to the terminating circuit 24' and another end connected to the wave detecting circuit 25. The terminating circuit 24' consists of a terminating resistor 241'. The terminal resistor 241' has an end connected to the end of the sub strip line 232 and has another end which is grounded or earthed. At any rate, the sub-strip line 232 is terminated by the terminating resistor 241' at the end thereof.

With this structure, the directional coupler 22' couples the sub strip line 232 only to a wave traveling in a particular direction in the main strip line 231, while completely ignoring a wave traveling in the opposite direction. In other words, a partial electric power of the transmission output signal Po is detected by the directional coupler 22' as an extracted signal. The extracted signal is supplied to the wave detecting circuit 25.

In addition, the transmission output signal Po is supplied to the isolator 33 via the main strip line 231. Outputted from the isolator 33, the amplified radio frequency signal is radiated as a transmission wave from the antenna 37 via the multiplexer 35.

The wave detecting circuit 25 consists of a diode 251, a resistor 252, and a capacitor 253. The wave detecting circuit 25 converts the extracted signal into a detected DC voltage Vdt. The detected DC voltage Vdt is supplied to the error amplifier 29.

On the other hand, the reference voltage varying part 27 is supplied with data (a control signal) indicative of frequency information from the data input terminal 13. On the basis of the data indicative of the frequency information, the reference voltage varying part 27 produces a selected reference voltage Vref. The selected reference voltage Vref is supplied to the error amplifier 29.

The error amplifier 29 compares the detected DC voltage Vdt with the selected reference voltage Vref to obtain an error voltage between the detected DC voltage Vdt and the selected reference voltage Vref and amplifies the error voltage into an amplified error voltage. The amplified error voltage is supplied to the power supply voltage control part 31. The power supply voltage control part 31 is supplied with a power supply voltage from the power supply terminal 15. The power supply voltage control part 31 controls the power supply voltage on the basis of the amplified error voltage to produce the controlled power supply voltage Vp which is supplied to the power amplifying part 21' in the manner which is described above.

With this structure, it is possible to vary the output of the power amplifying part 21' to reduce the power deviation within a band. That is, inasmuch as the wave detecting circuit 25 has a frequency characteristic, it is impossible to avoid the power deviation if the reference voltage Vref is fixed. In order to remove this defect, the reference voltage varying part 27 changes the reference voltage Vref in response to the control signal indicative of frequency information from the data input terminal 13. As a result, it is possible to make high-frequency output level power down step-by-step. However, in this case, the transmission output control apparatus 10' is disadvantageous in that a range of the transmission output is limited.

On the other hand, in order to resolve this problem, technique, which can easily control a level of the transmission output at a wide range, is disclosed, for example, in the above-mentioned JP-A 9-148945.

Referring to Fig. 2, a second conventional transmission output control apparatus 10" will be described in order to facilitate an understanding of the present invention. The illustrated transmission output control apparatus 10" is disclosed in the above-mentioned JP-A 9-148945.

The transmission output control apparatus 10" comprises a power amplifying part 21", a reference voltage generation circuit 27', the antenna 37, a transmission output detection circuit 39, a transmission output control circuit 41', a switching control circuit 43, and a drive voltage switching part 45'.

The power amplifying part 21" is supplied with the input radio frequency signal Pi from the radio frequency input terminal 11. The power amplifying part 21" comprises a drive amplifier 211, a transmission filter 212, and a power amplifier 213. The drive amplifier 211 is supplied with the input radio frequency signal Pi. In addition, the drive amplifier 211 is supplied with a drive voltage Vdr from the drive voltage switching part 41' in the manner which will later become clear. The drive amplifier 211 amplifies the input radio frequency signal Pi on the basis of the drive voltage Vdr to produce a drive signal Pd. The drive signal Pd is supplied to the transmission filter 212. The transmission filter 212 removes an unnecessary wave from the drive signal Pd to produce a filtered output signal Pf. The filtered output signal Pf is supplied to the power amplifier 213. The power amplifier 213 is supplied with a controlled power supply voltage Vp from the transmission output control circuit 41' in the manner which will later become clear. The power amplifier 213 amplifies the filtered output signal Pf on the basis of the controlled power supply voltage Vp to produce the transmission output signal Po.

The transmission output signal Po is radiated from the antenna 37 as the transmission wave. The transmission output signal Po is supplied to the transmission output detection circuit 39. The transmission output detection circuit 39 detects a level of the transmission output signal Po to produce the detected DC voltage Vdt. That is, the transmission output detection circuit 39 corresponds to a combination of the directional coupler 22' and the wave detecting circuit 25 as illustrated in Fig. 1. The detected DC voltage Vdt is supplied to the transmission output control circuit 41'.

On the other hand, the reference voltage generation circuit 27' is supplied with a control signal S1 from the control signal input terminal 13. Responsive to the control signal S1, the reference voltage generation circuit 27' selects, as the selected reference voltage Vref, one of a plurality of reference voltages to generate the selected reference voltage Vref. At any rate, the reference voltage generation circuit 27' corresponds to the reference voltage varying part 27 as illustrated in Fig. 1. The selected reference voltage Vref is supplied to the transmission output control circuit 41'.

The transmission output control circuit 41' compares the detected DC voltage Vdt with the selected reference voltage Vref to produce the controlled supply voltage Vp which is supplied to the power amplifier 213 in the power amplifying part 21". That is, the transmission output control circuit 41 corresponds to a combination of the error amplifier 29 and the power supply voltage control part 31 as illustrated in Fig. 1.

At any rate, a combination of the power amplifier 213, the transmission output detection circuit 39, the transmission output control circuit 41', and the reference voltage generation circuit 27' serves as an automatic output control amplification circuit in a feedback control system.

In addition, the selected reference voltage Vref is supplied to the switching control circuit 43. Responsive to the selected reference voltage Vref, the switching control circuit 43 supplies the drive voltage switching part 45' with a selection control signal S2 indicative of either a logic high level or a logic low level.

The drive voltage switching part 45' comprises first and second power sources 451' and 452', and a switch 453'. The first power source 451' is called an A power source while the second power source 452' is called a B power source. The first power source 451' produces a first output voltage Va while the second power source 452' produces a second output voltage Vb which is lower than the first output voltage Va. The first and the second output voltages Va and Vb are supplied to the switch 453'. The switch 453' is supplied with the selection control signal S2 from the switching control circuit 43. Responsive to the selection control signal S2, the switch 453' selects, as the drive voltage Vdr, one of the first through the second output voltages Va and Vb. More specifically, the switch 453' produces the first output voltage Va as the drive voltage Vdr when the selection control signal S2 indicates the logic high level. The switch 453' produces the second output voltage Vb as the drive voltage Vdr when the selection control signal S2 indicates the logic low level.

When the second output voltage Vb is selected as the drive voltage Vdr, the gain of the drive amplifier 211 is reduced, and the required gain of the power amplifier 213 is raised. Therefore, leakage to the output terminal of a high frequency signal at the time of inactivity of the power amplifier 213 is reduced, and the transmission output range is extended.

With this structure, the drive voltage Vdr for the drive amplifier 211 is changed on the selection control signal S2 and amplification degree of the power amplifier 213 is changed. Accordingly, it is possible to carry out a level control by combining both of the changing ranges. Specifically, in the example being illustrated, a range of the amplification degree of the power amplifier 213 is applicable with respect to two-stage drive voltage Vdr of a high drive voltage and a low drive voltage in the drive voltage switching part 45' for the drive amplifier 211.

However, even though the amplification degree of the wide range is obtained, the transmission output detection circuit 39 (or the wave detecting circuit 25) for detecting a level of the transmission output has a limited dynamic range between 15dB and 20dB. Accordingly, in a case where a power down function beyond 20dB is required, structure for setting to a power down output having a predetermined value is adopted by giving a fixed bias voltage to a voltage controlled variable attenuator composed of a pin diode and so on in a RF stage of a transmission system and by lowering a gain of the transmission system by means of removing the drive amplifier from the transmission system by cutting down a power supply for the drive amplifier.

The transmission output control apparatus 10" is disadvantageous in that it is impossible to obtain a stable transmission output in the case where the power down function beyond 20dB is required. This is because the automatic output control amplification circuit, which feeds an error of the transmission output with respect to the reference voltage Vref back to the power amplifying part 21", is put into an off state in a substantial power down state and it is therefore impossible to absorb variation in a gain of the amplifier in the transmission system due to fluctuations of ambient temperature. In addition, a circuit configuration is complicated in a case of carrying out correction corresponding to the fluctuation of ambient temperature and it is therefore impossible to avoid a large size.

Referring to Fig. 3, the description will proceed to a transmission output control apparatus 10 according to a preferred embodiment of this invention. The transmission output control apparatus 10 has the radio frequency input terminal 11 supplied with the input radio frequency signal Pi from a modulator (not shown), the control signal input terminal 13 supplied with a power down control signal, and the power supply terminal 15 supplied with the power supply voltage.

The transmission output control apparatus 10 comprises a power amplifying part 21, a directional coupler 22, the wave detecting circuit 25, the reference voltage varying part 27, the antenna 37, a transmission output control part 41, and a drive voltage switching part 45.

The power amplifying part 21 is supplied with the input radio frequency signal Pi from the radio frequency input terminal 11. The power amplifying part 21 comprises a variable attenuator 214, the drive amplifier 211, and the power amplifier 213. The variable attenuator 214 is supplied with the input radio frequency signal Pi from the radio frequency input terminal 11. The variable attenuator 214 has a voltage control terminal 214a which is supplied with a transmission output control signal from the transmission output part 41 in the manner which will later become clear. The variable attenuator 214 attenuates the input radio frequency signal on the basis of the transmission output control signal to produce an attenuated radio frequency signal. The attenuated radio frequency signal is supplied to the drive amplifier 211. The drive amplifier 211 is supplied with the drive voltage Vdr from the drive voltage switching part 45 in the manner which will later become clear. The drive amplifier 211 amplifies the attenuated radio frequency signal on the basis of the drive voltage Vdr to produce the drive signal. The drive signal is supplied to the power amplifier 213. The power amplifier 213 amplifies the drive signal to produce the amplified radio frequency signal as the transmission output signal Po. The transmission output signal Po is supplied to the directional coupler 22.

The directional coupler 22 is similar in structure and operation to the directional coupler 22' illustrated in Fig. 1 except that the terminating circuit is modified from that illustrated in Fig. 1 as will later become clear. The terminating circuit is therefore depicted at 24.

The directional coupler 22 comprises the coupling section 23 and the terminating circuit 24. The coupling section

23 comprises the main or primary strip line 231 and the sub or secondary strip line 232. In the example being illustrated, each of the main strip line 231 and the sub strip line 232 is implemented by a microstrip line. Therefore, the main strip line 231 is called a main microstrip line while the sub strip line 232 is called a sub microstrip line.

The main microstrip line 231 and the sub microstrip line 232 are formed on the printed wiring board (not shown) and arranged in parallel to each other with a space left therebetween. The main microstrip line 231 has an end connected to an output terminal of the power amplifying part 21 and another end connected to the antenna 37. The sub microstrip line 232 has an end connected to the wave detecting circuit 25. In addition, the sub microstrip line 232 has another end and a substantially middle position which are connected to the terminating circuit 24.

The terminating circuit 24 comprises first and second switches 241 and 242, and first and second terminating resistors 246 and 247. The first and the second switches 241 and 242 are controlled by the power down control signal from the control signal input terminal 13. The terminating circuit 24 connects the substantially middle position with a grounding or an earth terminal via a first series circuit consisting of the first switch 241 and the first resistor 246. In addition, the terminating circuit 24 connects the other end with the grounding or the earth terminal via a second series circuit consisting of the second switch 242 and the second resistor 247.

The power down control signal S3 indicates either a normal operating state or a power down state. When the power down control signal S3 indicates the normal operating state, the first switch 241 is turned on and the second switch 242 is turned off. When the power down control signal S3 indicates the power down state, the first switch 241 is turned off and the second switch 242 is turned on. At any rate, the terminating circuit 24 terminates, in response to the power down control signal, one of the other end and the substantially middle position of the sub microstrip line 232.

The power down control signal S3 is also supplied to the reference voltage varying part 27. The reference voltage varying part 27 comprises first and second variable resistors 271 and 272, and a switch 273. The first and the second variable resistors 271 and 272 are supplied the power supply voltage from the power supply terminal 15. The first and the second variable resistors 271 and 272 produce first and second reference voltages Vr1 and Vr2, respectively. The first reference voltage Vr1 is higher than the second reference voltage Vr2. The first and the second reference voltages Vr1 and Vr2 are supplied to the switch 273. The switch 273 is supplied with the power down control signal. Responsive to the power down control signal S3, the switch 273 selects, as the selected reference voltage Vref, one of the first and the second reference voltages Vr1 and Vr2. Specifically, when the power down control signal S3 indicates the normal operating state, the switch 273 selects the first reference voltage Vr1 as the selected reference voltage Vref. When the power down control signal S3 indicates the power down state, the switch 273 selects the second reference voltage Vr2 as the selected reference voltage Vref.

The selected reference voltage Vref is supplied to the transmission output control part 41. The transmission output control part 41 is supplied with the detected DC voltage Vdc from the wave detecting circuit 25. The transmission output control part 41 comprises a comparator 411, an up-down counter (U/D counter) 412, and a digital-to-analog converter (D/A converter) 413. The comparator 411 is supplied with the detected DC voltage Vdt and the selected reference voltage Vref. The comparator 411 compares the detected DC voltage Vdt with the selected reference voltage Vref to produce a comparison result. The comparison result is supplied to the up-down counter 412.

When the comparison result indicates that the detected DC voltage Vdt is lower than the selected reference voltage Vref, the up-down counter 412 carries out an up-count operation on a counted value or increments the counted value by one. When the comparison result indicates that the detected DC voltage Vdt is higher than the selected reference voltage Vref, the up-down counter 412 carries out an up-count operation on the counted value or decrements the counted value by one. The up-down counter 412 produces a digital signal indicative of the counted value in binary representation. The digital signal is supplied to the digital-to-analog converter 413. The digital-to-analog converter 413 converts the digital signal into an analog signal. The digital-to-analog converter 413 supplies the analog signal to the variable attenuator 214 as the transmission output control signal indicative of an attenuation amount.

The power down control signal S3 is further supplied to the drive voltage switching part 45. When the power down control signal S3 indicates the normal operating state, the drive voltage switching part 45 supplies the drive amplifier 211 with the drive voltage Vdr indicative of a normal gain of a rated transmission output. When the power down control signal S3 indicates the power down state, the drive voltage switching part 45 supplies the drive amplifier 211 with the drive voltage Vdr indicative of a power down gain to which the normal gain is reduced by 20dB. In the example being illustrated, the drive voltage Vdr indicative of the power down gain is substantially equal to zero voltage.

Now, the description will proceed to operation of the transmission output control apparatus 10 illustrated in Fig. 3. The description is first directed to operation in a case of a normal output. The description is continuously directed to operation in a case of a power down of 20dB.

In this case, the power down control signal S1 indicative of the normal operating state is supplied from the control signal input terminal 13 to the drive voltage switching part 45, the terminating circuit 24 of the directional coupler 22, and the reference voltage varying part 27. Under the circumstances, the drive voltage switching part 45 supplies the drive amplifier 211 of the power amplification part 21 with the drive voltage Vdr indicative of the normal gain. Responsive to the power down control signal S1 indicative of the normal operating state, the first and the second switches 241 and 242 of the terminating circuit 24 are turned on and off, respectively. In addition, the switch 273 of the reference voltage varying part 27 selects, in response to the power down control signal S1 indicative of the normal operating state, the first reference voltage Vr1 as the selected reference voltage Vref.

The input radio frequency signal Pi is supplied from the radio frequency input terminal 11 to the variable attenuator 214 of the power amplifying part 21. Responsive to the transmission output control signal supplied from the transmission output control part 41, the variable attenuator 214 attenuates the input radio frequency signal Pi to produce the attenuated radio frequency signal. The attenuated radio frequency signal is supplied to the drive amplifier 211. Responsive to the drive voltage Vdr indicative of the normal gain, the drive amplifier 211 amplifies the attenuated radio frequency signal into the drive signal. The drive signal is supplied to the power amplifier 213. The power amplifier 213 amplifies the drive signal into the transmission output signal Po. At any rate, a combination of the drive amplifier 211 and the power amplifier 213 amplifies the attenuated radio frequency signal up to a rated transmission output level.

The transmission output signal Po is supplied to the coupling section 23 of the directional coupler 22. The transmission output signal Po is radiated or transmitted from the antenna 37 via the main microstrip line 231 of the coupling section 23 in the directional coupler 22. Supplied to the main microstrip line 231, the transmission output signal Po is coupled to the sub microstrip line 232 to extract a part from the transmission output signal Po as the extracted signal. The extracted signal is supplied to the wave detecting circuit 25. The wave detecting circuit 25 converts the extracted signal into the detected DC voltage Vdt.

In the example being illustrated, the sub microstrip line 232 of the coupling section 23 is divided into two sub-lines. In the normal operating state, the sub microstrip line 232 has a coupling length so as to have degree of coupling of about 50%. In this event, the substantially middle position of the sub microstrip line 232 is grounded or earthed via the series circuit consisting of the first switch 241 and the first terminating resistor 246. It will be assumed that the transmission output control part 41, which constitutes an automatic power control (APC) circuit fed from the wave detecting circuit back to the variable attenuator 214, is implemented by a 3-volt device. In this event, the detected DC voltage Vdt supplied from the wave detecting circuit 25 is set to have one through two volts around the center thereof.

The detected DC voltage Vdt is supplied to the comparator 411 of the transmission output control part 41 together with the selected reference voltage Vref which is equal to the first reference voltage Vr1 so that the transmission output is maintained to a rated voltage.

It will be presumed that the detected DC voltage Vdt is higher than the selected reference voltage Vref (or the first reference voltage Vr1). In this event, the comparator 411 determines that the transmission output is higher than a rated value to produce, as the comparison result, a down instruction signal. Responsive to the down instruction signal, the up-down counter 412 decrements the counted value by one. Inasmuch as the counted value is decremented by one in the up-down counter 412, the digital-to-analog converter 413 produces the transmission output control signal indicative of a DC voltage which is lowered than a current voltage by a portion corresponding to one count or one bit. The transmission output control signal is supplied to the voltage control terminal 214a of the variable attenuator 214. Inasmuch as the DC voltage of the transmission output control signal is lowered, the attenuation amount in the variable attenuator 214 increases. As a result, the transmission output control circuit 10 operates so that the transmission output is lowered.

It will be assumed that the detected DC voltage Vdt is lower than the selected reference voltage Vref (or the first reference voltage Vr1). In this event, the comparator 411 determines that the transmission output is lower than the rated value to produce, as the comparison result, an up instruction signal. Responsive to the up instruction signal, the up-down counter 412 increments the counted value by one. Inasmuch as the counted value is incremented by one in the up-down counter 412, the digital-to-analog converter 413 produces the transmission output control signal indicative of the DC voltage which is raised than the current voltage by a portion corresponding to one count or one bit. Inasmuch as the DC voltage of the transmission output control signal is raised, the attenuation amount in the variable attenuator 214 decreases. As a result, the transmission output control circuit 10 operates so that the transmission output is raised.

In a radio telephone set of the personal handyhone system (PHS), operation of the above-mentioned automatic power control is repeated every transmission burst so that the detected DC voltage Vdt for the transmission output signal Po is equal to the first reference voltage Vr1. As a result, the transmission output is stabilized at the rated value.

Now, the description will proceed to operation in a case of the power down state. In the example being illustrated, the power down state is a state where the power down of 20dB is made. Under the circumstances, the power down control signal S3 indicative of the power down state is supplied from the control signal input terminal 13 to the drive voltage switching part 45, the terminating circuit 24 of the directional coupler 22, and the reference voltage varying part 27.

In this event, the drive voltage switching part 45 supplies the drive amplifier 211 of the power amplification part 21 with the drive voltage Vdr indicative of the power down gain. Inasmuch as the power supply for the drive amplifier 211 is cut down, a gain for a transmission system is lowered by about 20dB in comparison with the rated transmission output.

In addition, the switch 273 of the reference voltage varying part 27 selects, in response to the power down control signal S1 indicative of the power down state, the second reference voltage Vr2 as the selected reference voltage Vref.

The second reference voltage Vr2 is equal to a reference voltage on the power down. Responsive to the power down control signal S1 indicative of the power down state, the first and the second switches 241 and 242 of the terminating circuit 24 are turned off and on, respectively. Accordingly, the sub microstrip line 232 of the coupling section 23 has a coupling length which is longer than that in the normal operating state. Accordingly, the coupling section 23 has a degree of coupling which is raised in comparison with that in the normal operating state. As a result, it is possible to expand a dynamic range in the detected DC voltage Vdt detected by the wave detecting circuit 25. Therefore, the compatator 411 compares the expanded detected DC voltage Vdt with the selected reference voltage Vref or the second reference voltage Vr2.

Inasmuch as operation for obtaining the transmission output stabilized to the rated value is similar in a case of the above-mentioned rated output, the operation therefor is omitted for the purpose of simplification of the description.

While this invention has thus far been described in conjunction with the preferred embodiment thereof, it will now be readily possible for those skilled in the art to put this invention into various other manners. For example, although the transmission output control circuit according to the above-mentioned embodiment is operable at two operating modes of the rated output and a power down output and comprises the directional coupler having two degrees of coupling, the power down output further may be divided into N states, where N represents a positive integer which is not less than two. In this event, the reference voltage varying part may comprise (N + 1) variable resistors and the terminating circuit may comprise (N + 1) series circuits each of which consists of a switch and a terminating resistor.

Each feature disclosed in this specification (which term includes the claims) and/or shown in the drawings may be incorporated in the invention independently of other disclosed and/or illustrated features.

The text of the abstract filed herewith is repeated here as part of the specification.

In a transmission output control apparatus including a power amplifying part, a directional coupler, a wave detecting circuit, a reference voltage generating arrangement, a transmission output control part, and a drive voltage switching part, the directional coupler comprises a coupling section and a terminating circuit connected to the coupling section for terminating the coupling section. The coupling section includes a main strip line and a sub strip line which are arranged in parallel to each other. The terminating circuit is connected to a plurality of different positions of the sub strip line. The terminating circuit selectively terminates one of the different positions of the sub strip line in response to a control signal.

Claims:

1. A directional coupler comprising:

a coupling section comprising a main strip line and a sub strip line which are arranged in parallel to each other; and,

a terminating circuit, connected to said coupling section, for selectively terminating one of a plurality of different positions of said sub strip line in response to a control signal, thereby changing a degree of coupling of said directional coupler by changing a coupling length of said sub strip line.

2. A directional coupler as claimed in claim 1, wherein said terminating circuit comprises a plurality of series circuits which are connected between the respective different positions of said sub strip line and a grounding terminal, each of said series circuits consisting of a switch and a terminating resistor, said switch being turned on or off in response to the control signal.

3. A power transmission output control apparatus comprising:

a power amplifying part, supplied with an input radio frequency signal, a transmission output control signal, and a drive voltage, for amplifying the input radio frequency signal in response to the transmission output control signal and the drive voltage to produce a transmission output signal;

a directional coupler, connected to said power amplifying part and supplied with a control signal, for extracting, in response to the control signal, a part of the transmission output signal as an extracted signal, said directional coupler comprising a coupling section and a terminating circuit connected to said coupling section for terminating said coupling section, said coupling section comprising a main strip line and a sub strip line which are arranged in parallel to each other, said terminating circuit being connected to a plurality of different positions of said sub strip line, said terminating circuit selectively terminating one of the different positions of said sub strip line in response to the control signal;

a wave detecting circuit, connected to said directional coupler, for detecting the extracted signal to produce a detected DC voltage;

reference voltage generating means for generating a reference voltage;

a transmission output control part, connected to said power amplifying part, save wave detecting circuit, and said reference voltage generating means, for comparing the detected DC voltage with the reference voltage to supply the transmission output control signal to said power amplifying part; and,

a drive voltage switching part, connected to said power amplifying part and supplied with the control signal, for supplying said power amplifying part with the drive voltage in response to the control signal.

4. A transmission output control apparatus as claimed in claim 3, wherein said terminating circuit comprises a plurality of series circuits which are connected between the respective different positions of said sub strip line and a grounding terminal, each of said series circuits consisting of a switch and a terminating resistor, said switch being turned on or off in response to the control signal.

5. A transmission output control apparatus as claimed in claim 3, wherein said power amplifying part comprises:

a variable attenuator, supplied with the input radio frequency signal and connected to said transmission output control part, for attenuating the input radio frequency signal on the basis of the transmission output control signal to produce an attenuated radio frequency signal;

a drive amplifier, connected to said variable attenuator and said drive voltage switching part, for amplifying the attenuated radio frequency signal on the basis of the drive voltage to produce a drive signal; and,

a power amplifier, connected to said drive amplifier, for amplifying the drive signal to produce the transmission output signal.

6. A transmission output control apparatus as claimed in claim 3, wherein said reference voltage generating means comprises a reference voltage varying part supplied with the control signal, said reference voltage varying part comprising:

a plurality of variable resistors for producing a plurality of reference voltages; and,

a switch, connected to said plurality of variable resistors and supplied with the control signal, for selecting one of the plurality of reference voltages as a selected reference voltage to supply the selected reference voltage to said transmission output control part.

7. A transmission output control apparatus as claimed in claim 3, wherein said transmission output control part comprises:

a comparator, connected to said wave detecting circuit and said reference voltage generating means, for comparing the detected DC voltage with the reference voltage to produce a comparison result;

an up-down counter, connected to said comparator, for carrying out an up-down counting operation on a counted value in response to the comparison result to produce a digital signal indicative of the counted value; and,

a digital-to-analog converter, connected to said up-down counter, for converting the digital signal into the transmission output control signal.

8. A transmission output control apparatus as claimed in claim 5, wherein the control signal is a power down control signal indicative of one of a normal operating state and a power down state, said drive voltage switching part supplying said drive amplifier with the drive voltage indicative of a normal gain of a rated transmission output, said drive voltage switching part supplying said drive amplifier with the drive voltage indicative of a power down gain when the power down control signal indicates the power down state.

9. A transmission output control apparatus as claimed in claim 8, wherein the power down gain is equal to a gain to which the normal gain is reduced by 20dB.

10. A transmission output control apparatus as claimed in claim 9, wherein the drive voltage indicative of the power down gain is substantially equal to zero voltage.

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Application No:	GB 9918976.3	**Examiner:**	Dr Andrew Glanfield
Claims searched:	1-10	**Date of search:**	13 March 2000

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Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.R): H1Q (QFE, QFF, QHC, QHE, QHH, QHX), H1W (WCAA, WCAX, WCX)

Int Cl (Ed.7): H01P (5/18, 5/19, 5/20, 5/22), H01Q

Other: ONLINE: EPODOC, JAPIO, WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	EP 0828308 A1	(MATSUSHITA) see whole document.	
A	EP 0291694 A1	(SIEMENS) see WPI abstract Accession number 1988-331308.	
X	JP 06 2159502	(ALPS ELECTRIC) see PAJ abstract and figure.	1, 2

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