CHAPTER - 6

PIN DIODE CONTROL CIRCUITS
FOR
WIRELESS COMMUNICATIONS
SYSTEMS

NOTES

PIN DIODE CONTROL CIRCUITS FOR WIRELESS COMMUNICATIONS SYSTEMS

INTRODUCTION

Chapter 6 discusses PIN Control Circuits that are appropriate for Wireless Communications Systems, from HF Band (2-30 MHz) through 2.4 GHz. Many of the control circuits discussed in Chapter 2 (PIN Diode RF Switches) & Chapter 3 (PIN Diode RF Attenuators) are suitable for specific wireless system applications. Some of the most important circuit applications, using PIN diodes, are discussed below.

PIN DIODE ANTENNA TRANSMIT/RECEIVE SWITCHES

Transmit / Receive Antenna Switches are commonly used to connect the Transceiver's Antenna to either the Transmitter port or the Receiver port. Physically, this circuit is a Single Pole - Double Throw Switch (SPDT) that in either position, must have very low loss in the "ON" State (less than 0.5 dB) and high Isolation (typically, 30 dB) in the "off" State. Several T / R Switch circuits appeared in Chapter 2 and are repeated here as Figures 6.1 & 6.2.

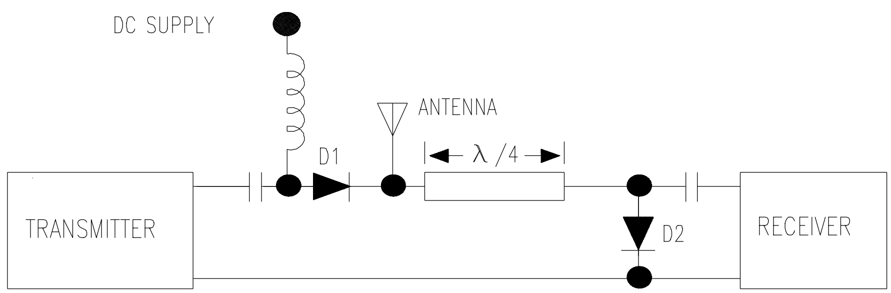

Figure 6.1 QUARTER WAVE ANTENNA SWITCH

Figure 6.1 is a narrow band SPST switch configured to switch the Antenna Port between either the Transmitter or Receiver Ports. The Quarter-wavelength line is the narrow band limitation, but for systems that have been allocated only 5% to 10% signal bandwidth, this is a very practical solution. When both D1 & D2 are forward biased, the Transmitter is connect to the Antenna, and the Receiver is protected by the isolation network of D2 terminating the quarter wavelength line. When D1 & D2 are reversed biased, the Transmitter Port is isolated by D1, and the quarter wavelength line and the Receiver Port are connected to the Antenna. The biasing scheme is very simple, requiring only one RF Choke Coil and a few d-c Blocking Capacitors. The quarter wavelength line can be simulated by a low-pass LC network to conserve board space.

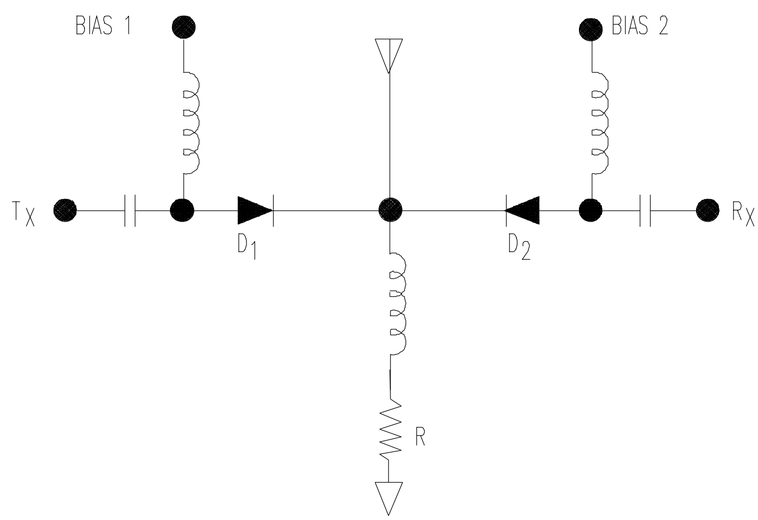

Figure 6.2 BROADBAND ANTENNA SWITCH

Figure 6.2 is a broad band SPDT switch, but the biasing scheme is more complex. It requires two bias tee's and a d-c return coil because D1 & D2 are alternately biased forward or reverse. For example, when the Transmitter is "ON" (and the Receiver "OFF"), D1 is forward biased and D2 is reversed biased. The Transmit / Receive Isolation State now depends solely on the Reverse Bias Capacitance of D2. The two bias conditions are exchanged when the Receiver is "ON". Isolation can be increased by using two PIN diodes in series instead of one for "D2".

The MICROSEMI UPP1001 Powermite® series of low distortion surface mount packaged PIN diodes were designed for low distortion Wireless Communications handset applications where battery power management is an extremely critical issue with circuit designers. They are excellent for handset, mobile, or base station applications where very low Insertion Loss (I_L) is required. The I_L of the UPP1001, mounted in a 50 Ohm network, with 10 mA forward bias current is less than 0.1 dB. The UPP1000's have a nominal Capacitance (Ct) of 1.25 pF, which is adequate for 5% to 10% bandwidth applications (similar to Figure 6.1) without inductive tuning. To use this series in broader applications (similar to Figure 6.2), either two devices can be used in series or a single device can be placed in one branch of a tuned switch design.

PIN DIODE ANTENNA DUPLEXING SWITCH

DUPLEX (communications) pertains to a simultaneous two-way independent transmission in both directions [1]. HALF-DUPLEX (communications) pertains to an alternate, one way at a time, independent transmission. In this sense, the Duplexing Switch, shown both in block diagram form in Figure 6.3 (a) and schematic form in Figure 6.3 (b), is a half-duplexing switch.

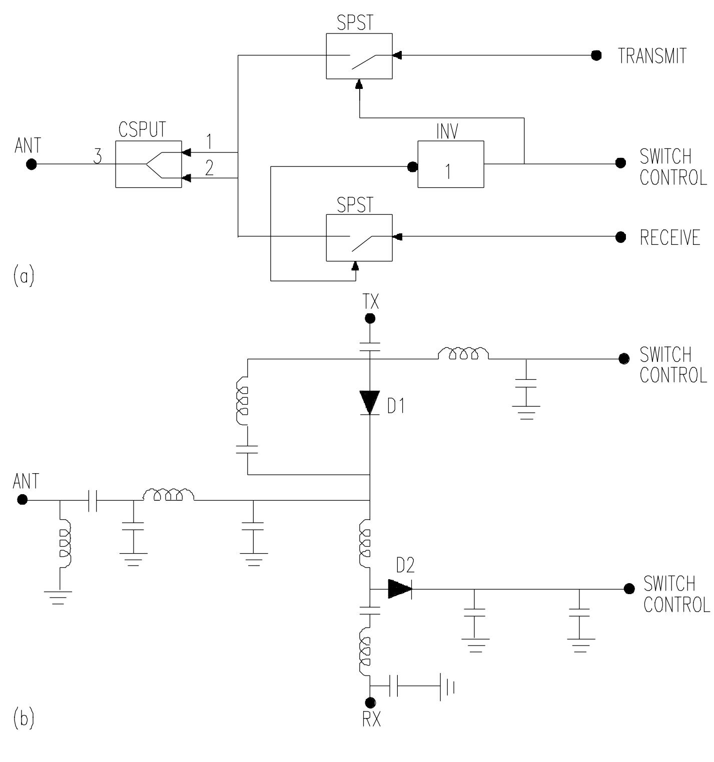

Figure 6.3 Duplexing Switch For Cellular Telephone: (a) Block diagram & (b) Schematic

The block diagram emphasizes the basic function blocks of the duplexing switch. The receive or transmit signals connect to the Antenna port via a power combiner or Y-Junction, which provides a matched, low loss connection to either signal path. The individual switches are SPST switches, as discussed in Chapter 2. The PIN diode shunts the resonant circuit that determines the pass band of either the receive or the transmit switch. A single dual polarity switch control suffices for both switches, since a polarity inverter provides the opposite polarity for the receive switch.

The receive channel is 40 MHz to 60 MHz below the transmit channel, depending on the specific system application. If Figure 6.3 represents a GSM cellular phone, the receive switching circuit is tuned to 890 to 915 MHz and the transmit switching circuit is tuned to 935 to 960 MHz band. The antenna channel filter network passes both the transmit and receive bands.

PIN DIODE ANTENNA DIVERSITY & T/R SWITCH FOR CELLULAR TELEPHONES

This antenna switch for cellular telephones provides the antenna T/R function as well as the antenna space diversity function for cellular telephones and is installed in vehicles. If provided with a switched d-c- connection port to charge the telephone's battery pack, it is referred to as a "docking switch". The battery pack charging function is not shown because our concern here is with RF switching circuits.

A functional diagram of the antenna diversity and T/R switch is shown in Figure 6.4.

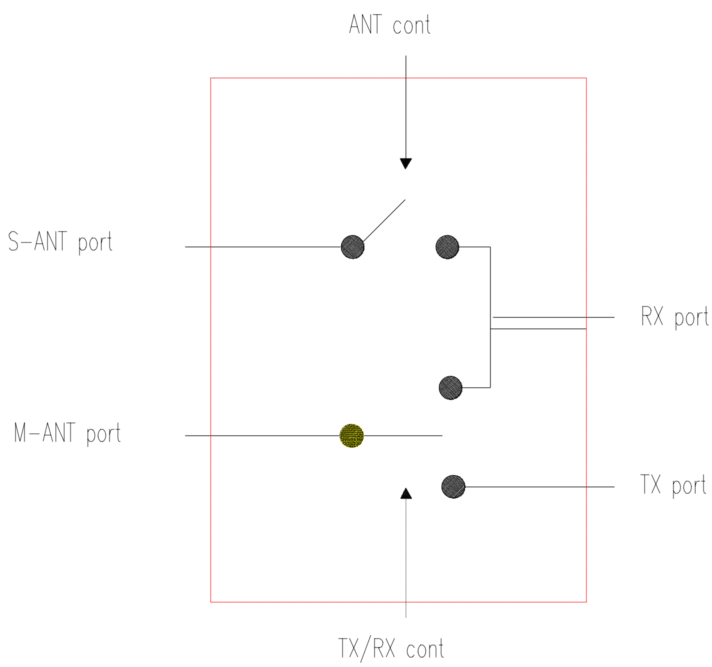

Figure 6.4 PIN Diode Antenna Diversity & T/R Switch for Cellular Telephones

This composite switch contains both a SPDT and a SPST switch (Chapter 2) and would be suitable for either United States or European cellular systems. The T/R switch function is performed by the SPDT switch. The added feature is that the SPST switch is positioned by a signal strength circuit to provide connectivity to the antenna that provides the stronger receive signal to the receive port.

In a typical vehicle mounted application, this composite switch would be designed to switch transmitter power of +38 dBm with a 1 dB compression point of +35 dBm. Isolation between transmit and receive ports would be about

30 dB. Both isolation and 1 dB compression point are specified with the transmitter connected to the main antenna (M-ANT port). The maximum switching speed of the SPST and the SPDT is 1 us. VSWR at all input and output ports is less than 2:1 for all possible positions of the two switches. The SPDT switch could be rendered either as a series PIN diode switch (Figure 2.7) or as a shunt PIN diode switch (Figure 2.8), depending on system design parameters such as bandwidth, power handling, and circuit construction technology. The UPP9401 would be an excellent choice for surface mount SPDT and SPST switches.

PIN DIODE ELLIPTICAL DIRECTIONAL ANTENNA ARRAYS FOR WIRELESS DATA MODEMS

Several firms are adopting an elliptical directional antenna array to provide space diversity for their mobile wireless data modems. The serving base station would have such antenna array as well. An array signal processor, with a sufficient number of antenna elements, can reduce the volatility of the RF link between a mobile unit and the base station. The design concepts were originally described for base stations in [1,2].

A simplified version of the base station array concept can be implemented to lower the BER and to diminish the effects of multi-path fading and co-channel interference for a mobile data modem also. A multi-element array, consisting of either a 6 or 8 antenna elements is used to:

Improve the “front-to-back” ratio (directivity) of the array

Improve the “self-interference” problem of dual arrays

Improve the antenna gain (6 elements yields 6 dB antenna gain)

The available power (P_{av}) from the transmitter output stage depends on the system’s overall linearity and BER specification (Appendix C). PIN diode switches are used to switch the elements of the antenna array, because the power output stage-antenna switch interface can be optimized to achieve the most linear solution [3]. If the effective radiated power from the data modem is 36 dBm @ 2.4 GHz, various combinations of antenna elements and available power gain will result in the following solutions:

Antenna Elements	Antenna Gain	Power Output	Linearity*
8	8 dB	28 dBm	more linear
6	6 dB	30 dBm	less linear

* A quantitative statement of linearity depends on their system parameters than those considered here.

With fewer antenna elements, the transmitter output gain is increased to obtain the required output power, thus decreasing the transmitter-switch overall linearity.

The elliptical antenna array is a specially configured switch matrix. It is a 1 x N switch matrix, where N is either 6 or 8, depending on the particular data modem antenna design. The array is center fed and connectivity between the input feed and the branch antenna elements is provided by a divider/combiner network.

A radial combiner geometry, is given in [3], which has circular symmetry, consists of an array of branch transformers (50 Ohms to 150 Ohms), that connect the antenna elements to the central junction or antenna feed port. An elliptical antenna array would require a more complex network of branch transformers since elliptical symmetry is not so simple as circular symmetry. However, the focus here is on the PIN diode switch design and bias conditions. The analysis of the shunt mounted PIN diode switches [5] in the branch arms of the radial combiner is generally applicable to other combiner geometries as well.

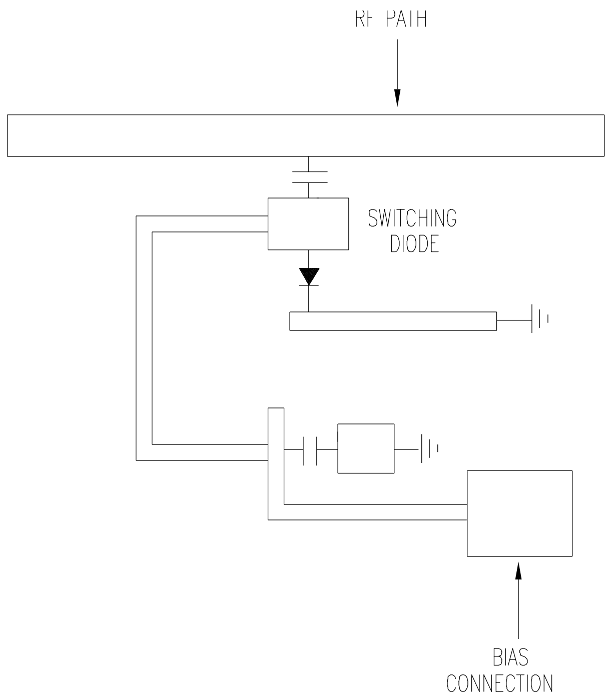

Figure 6.5 Shunt Mounted PIN diode Switching Network

The shunt mounted PIN diode switch is placed about a quarter wavelength from the central junction so that it appears as a virtual short circuit at the point of connection (or an open circuit at the central junction). Each branch antenna switch is connected to the central junction with a transmission line transformer (50 Ohms to 150 Ohms). The exact position of the switch along the transformer is determined by modeling the switch sub-network and transformer combination until a high reflection coefficient at 0 degrees phase angle is observed at the 150 Ohm end of the transformer. This modification of the switch position ensures that an open circuit is seen at the center of the radial switch for antenna ports that are turned off. Figure 6.5 shows the location of the PIN diode and the compensating network.

Shunt switches work by having a PIN diode connected between the transmission and the ground plane. When the diode is in the low impedance state, a short circuit is created and the incident wave traveling along the transmission line is totally reflected. If the PIN diode is in a high impedance state, it appears not to be in the circuit at all, allowing the incident wave to pass unimpeded.

In practice, the PIN diode has finite dimensions and its performance in the “ON” and “OFF” states is affected by the Resistance and Capacitance of the PIN diode junction and the parasitic reactances of the diode package. These effects are compensated by incorporating the PIN diode’s equivalent circuit into the sub-network design model that determines the design of the compensating network.

PIN Diode Automatic Gain Control (AGC) Loops

Automatic Gain Control (AGC) is an important power control function for mobile communications systems. A base station establishes the connection between two mobile units or cellular phones within the cell area that it controls. It also maintains that link until the transmitted signal of either of the two mobile units is sufficiently weak that the specified Quality of Service (QoS) cannot be maintained. The weaker station is then handed off to an adjacent call's base station controller.

The AGC circuit in the mobile unit is the key element to the establishment and maintenance of a call. A base station monitors the signal strength of each mobile unit under its control. It transmits a control signal to the mobile unit's AGC circuit (via the link maintenance channel) when its transmitter output power must be adjusted to maintain call continuity. Thus, the mobile unit's AGC function is a fundamental part of the base station call link control function.

A block diagram of a generic RF- AGC circuit was shown in Figure 3.5 (Chapter 3). Figure 6.6 a typical block diagram for the AGC function in a cellular radio.

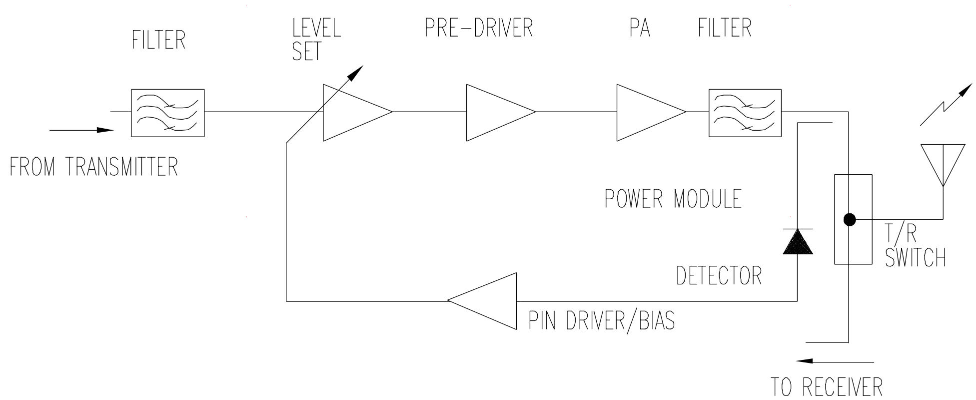

Figure 6.6 Typical AGC Loop For A Cellular Radio

The base station control signal is detected by the detector circuit in the decoupled arm of the AGC circuit. This signal is amplified and fed to the level set attenuator to adjust the input power to the pre-driver. If the mobile unit is approaching the base station, it will signal for a larger amount of attenuation in the mobile unit's level set to provide the smaller amount of transmitter power needed to maintain the call. Attenuation is decreased if more transmitter output power is needed for call link maintenance. Obviously, if the base station senses that the mobile unit cannot increase its transmitter power further, the base station call hand off controller initiates the procedure for call handoff to an adjacent cell's base station.

The level set attenuator circuit can be chosen from the numerous designs presented in Chapter 3. The usual choices are the Bridged TEE PIN Diode Attenuator (Figure 3.12) or the PIN Diode π Attenuator (Figure 3.14). The UM9301 would be an excellent choice for this AGC level set at UHF and above.

OPTIMIZATION OF RF TRANSMITTER LINEARITY

The important parameters for optimizing the overall performance of the transmitter - T/R Switch combination are discussed in reference [4], which appears in Appendix C.

APPLICATION	**RECOMMENDED PIN DIODE TYPES**
WIRELESS	UPP1001-1004, UPP9401