

# Identification Friend or Foe (IFF Systems) use PIN Diodes

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Imagine that you are the pilot of the world's premier electronic warfare aircraft, an EA-6B Prowler. You have just taken off from the flight deck of the USS Nimitz (CVN 68), somewhere in the Persian Gulf. Your mission is to patrol over Northern Iraq with your squadron of F/A-18's, to intercept Iraqi fighters, and to suppress Missile Launch Radar with high power jamming beams. Your Heads-up Display tells you there is a squadron of aircraft off your port wing some 25 miles away. You interrogate those bogeys by pressing the IFF button on your joy stick. How does this interrogation system perform its task and what



circuit functions in your IFF system use discrete semiconductor devices?

Modern IFF system technology, used by military aircraft and ground control sites, is a direct outgrowth of the World War II IFF systems. IFF System circuit details are highly classified. Most IFF interrogators operate somewhere in L-Band (1 to 2 GHz). How does the basic interrogation system work?

All military aircraft carry an interrogator-receiver unit and a transponder unit. The pilot energizes the interrogation unit and after a few milliseconds, the bogey's transponder unit replies (if it is friendly). This is a two beam or channel system. The interrogator operates at 1030 MHz and the identity reply unit operates at 1090

MHz. These are specified by the FAA for commercial air control and are not the same for military aircraft. The basic system concepts are the same, however.

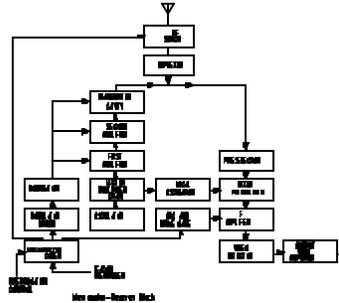


Figure 1. Interrogator-Receiver Block Diagram

To give the reader a feel for the complexity of an IFF System, Figure 1 shows the block diagram of a typical Interrogator-Receiver unit [1]. In this unit, PIN diodes would be used in the RF Switch, the Duplexer, and for the Automatic Gain Control (AGC) function in the amplifier stages. A typical IFF Transponder unit is shown in Figure 2. In the Transponder unit [1], the PIN diodes could be used in the Preselector

need to know the important IFF System Technical Features.

Features	IFF Interrogator	IFF Transponder (Reply Path)
Frequency	1030 +/- 0.2MHz	1090 +/- 0.2MHz
Pulse-Pair Spacing	3 us	1.45 us
Pulse Width	0.8 us	0.8 us
Typical PRF	300-400	300-400
Peak Output Power	1-1.5 KW	0.5KW

From these technical features, we deduce that these antenna switches should be capable of handling high peak power. The Interrogator transmits a sequence of coded pulse pairs whose (individual) pulse width is brief (0.8 us) and the Pulse Repetition Frequency (PRF) is relatively low, so the average output power is relatively low (less than 50 Watts). In a 50 Ohm transmission line, the peak pulse voltage is less than 400 Volts. A conservative switch design can be accomplished with UM7504's. In L-Band, 50 Volts of reverse bias and 50 mA of forward bias current are adequate to keep the

Filter, in the AGC function of the Transmitter, and in the Modulator.

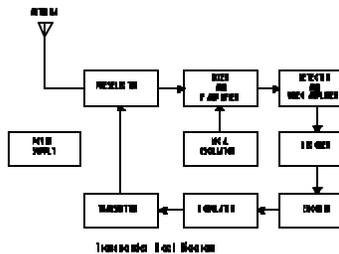


Figure 2. IFF Transponder Block Diagram

## ANTENNA SWITCH

To specify the antenna switch, we

dissipated power low (less than 100 mW).

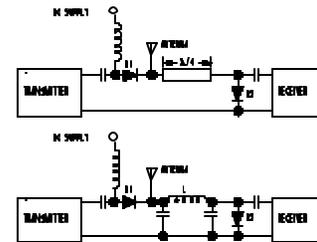


Figure 3. Quarter Wave Antenna Switch

The Transmit / Receive switch design can be accomplished with the relatively narrow band Quarter Wave PIN Diode Antenna Switch [2] shown in Figure 3, using UM7504's for D1 and D2. The quarter wavelength line reflects a short circuit to the transmitter port when the switch is in the ON State

(D1 & D2 are forward biased), thus protecting the receiver when the transmitter is connected to the antenna. Conversely, when the switch is in the OFF state (D1 & D2 are reverse biased), the receiver is connected to the antenna and the transmitter is disconnected.

**TRANSMITTER AGC CIRCUIT**

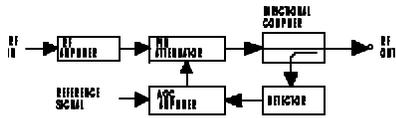


Figure 4. Microwave AGC Circuit

A Microwave Transmitter AGC Circuit [2] is shown in Figure 4. The PIN diode attenuator may be a simple reflective attenuator, such as a series or shunt diode mounted across the transmission line. Some AGC attenuators are more complex networks that maintain impedance match to the input power source and load as the attenuation is varied across its dynamic range. These matched AGC attenuators exhibit less frequency pulling and lower signal distortion and are especially appropriate for high power AGC circuits. A Quadrature Hybrid Matched Attenuator, using shunt mounted PIN diodes, is shown in Figure 5.

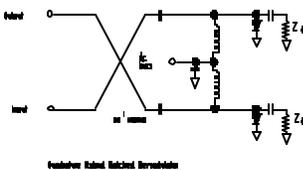


Figure 5. Quadrature Hybrid Matched Attenuator

The quadrature hybrid configuration can control twice the power of the simple series or shunt diode configuration because the incident power is divided into two paths by the hybrid. The purpose of the branch load resistors is to make the AGC circuit less sensitive to differences between individual diodes and to balance the hybrid, allowing the 3 dB increase in power handling.

**TRANSPONDER MODULATOR CIRCUIT**

PIN diodes are the preferred active elements for Microwave Power Modulators. The switching speed must be fast enough for the PIN diode to respond to the modulating signal without introducing non linear modulation effects. The PIN diode's minority carrier lifetime should be long enough to provide a low level of Microwave Intermodulation Distortion. PIN Diode Modulator Circuit configurations are similar to PIN diode attenuator circuits [2]. Since the modulation signal is fed into the d-c bias port, the bias circuitry must be sufficiently broadband that the modulation signal is not distorted. Isolation between the modulation insertion port and the Microwave Carrier input port must be at least 50 to 60 dB for linear high power modulation. The Microwave circuitry should be sufficiently broadband to terminate the Microwave carrier and both sidebands in 50 Ohms.

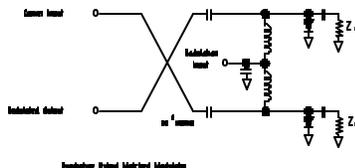


Figure 6.

Quadrature Hybrid Matched Modulator Circuit

For pulsed amplitude modulators, the Quadrature Hybrid Modulator Circuit in Figure 6 satisfies the bandwidth and isolation requirements for linear modulation of the Microwave Carrier Wave. If the Microwave Carrier is pulse modulated, no transmitter signal is present between pulses. The modulator in Figure 6 is a PIN diode switch circuit that is rapidly biased ON and OFF according to the alternating polarities of the interrogation pulses. Thus, the Microwave Carrier is not transmitted during the modulator OFF state.

Because of the exacting requirements of linearity of a specified dynamic range

of operation, both Attenuator and Modulator PIN Diodes have thick I- regions and relatively long lifetimes. There are design trade-offs between switching speed (needed for pulse amplitude modulation) and long lifetime (needed for linearity and low distortion). The UM 4300 series, the UM 7300 series, and the UM9301 series of PIN diodes are generally the devices of choice for the circuits shown in Figures 5 & 6. However, for fast pulse, high power microwave modulators, the UM 4000 series of PIN diodes should be considered as well.

**FURTHER ANTENNA SWITCH CONSIDERATIONS**

The location of the airborne antenna system on the aircraft is a critical element in system performance. Air-to-air Military IFF is further complicated by the need for spherical coverage. Some designs use an antenna diversity system or dual input transponder with two antennas and two receiver front ends. Reply pulses from both antennas are compared for signal strength and a PIN diode diversity switch sets the transmitter's output to the antenna having the strongest input signal. In this way, spherical coverage is obtained, and the reply is transmitted on the antenna facing the interrogating unit. Interrogation and Transponder units normally operate in conjunction with a primary radar suite, because of system integration considerations. Hence the IFF antenna is part of the radar's antenna array.

For additional information on Microsemi's PIN Diodes contact Bill Doherty at Microsemi Watertown at (617)926-0404 or email at [bdoherty@microsemi.com](mailto:bdoherty@microsemi.com).

**REFERENCES**

- [1] Merrill I. Skolnik, Radar Handbook, McGraw-Hill Book Company, New York, 1988
- [2] The PIN Diode Circuit Designers' Handbook, Microsemi Corp, 1998, Chapters 3,4, &5