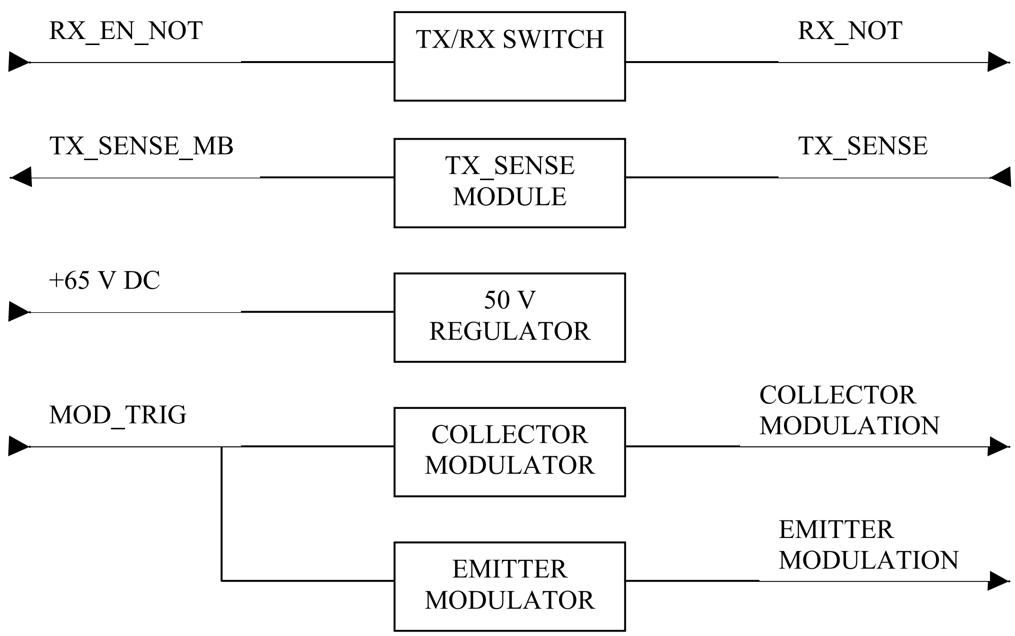
KT 73 Transmitter/Modulator Module (Theory of Operation)

1.0 Modulator Board

The modulator board drives the transmitter according to the signals received from the RLSI chip on the main board. The KT73 modulator can be divided into the five major blocks: TX_SENSE module, 50V regulator, collector modulator, emitter modulator, and TX/RX switch. Figure 1 Modulator Board Block Diagram below shows these functions. The modulator schematic is KPN 002-08274-0020.

Figure 1 Modulator Board Block Diagram



1.1 TX_SENSE Module

The TX_SENSE circuit detects the transmitted pulse, converts it into TTL format and sends it to the RLSI. The detected signal is used to verify that the squitter function is working. The detection circuit consists of a detector diode CR2, resistor R5, and capacitor C18 on the transmitter board. The detected RF is sent to the modulator board via E4 and is then buffered by Q12 on the modulator board. Modulator board U1 whose output is TTL compatible then inverts the TX_SENSE.

1.2 50 V Regulator

The 50 V regulator takes the 65 V from the power supply and regulates it to 50 +/- 1.5 VDC. The circuit uses two power transistors Q2 and Q3 (both Darlington) on the modulator board and a voltage divider network that supplies the base drive to the two Darlington transistors. The regulator consists of Q1, CR3, R4, R5, R34, and R6 on the modulator board. In a steady state, when the 65 V line is at 65 V, the regulator keeps the bases of the Q2 and Q3 Darlington at 50 VDC. As the voltage on the 65 V line drops, the base voltage for Q3 drops, reducing the collector current of Q3 and raising the base currents for the darlingtons. The is the as the 65 V line drops, the voltage drop through the darlingtons is decreased, and the collector voltages for the RF transistors stay at 50 VDC.

1.3 Collector Modulator

The collector modulator is used to increase the fall time of the RF output pulse. The final RF amplifier is powered by a series of 50 V collector voltage pulses that correspond to MOD_TRIG pulses. The collector voltage starts with the rising edge of each MOD_TRIG pulse and end when the gate of Q10 discharges to below its threshold level. MOD_TRIG is inverted by I1 and fed to Q11 through C24. I1 also provides isolation between MOD_TRIG and the 65 V line. Transistor Q11 is a medium power p-channel FET that drives the high current driver Q10, IRF540. Integrated circuit I1 pulls one end of C24 from 12 V to ground, causing a 12 V drop in the gate to source voltage of Q11. The threshold voltage, V_{GS} of Q11 in negative 2-4 volts, so the falling on 12 V pulse drives Q11 into saturation. The result is a 65 pulse on R28 and R26 that turns on Q10, which then delivers a 50 V pulse to the collector of the final amplifier. R28 and the capacitance of Q10 from gate to source control the rate, at which the gate voltage of Q10 is discharged, effectively slowing down the fall time of the 50 volt pulse that appears on the collector of the final amplifier.

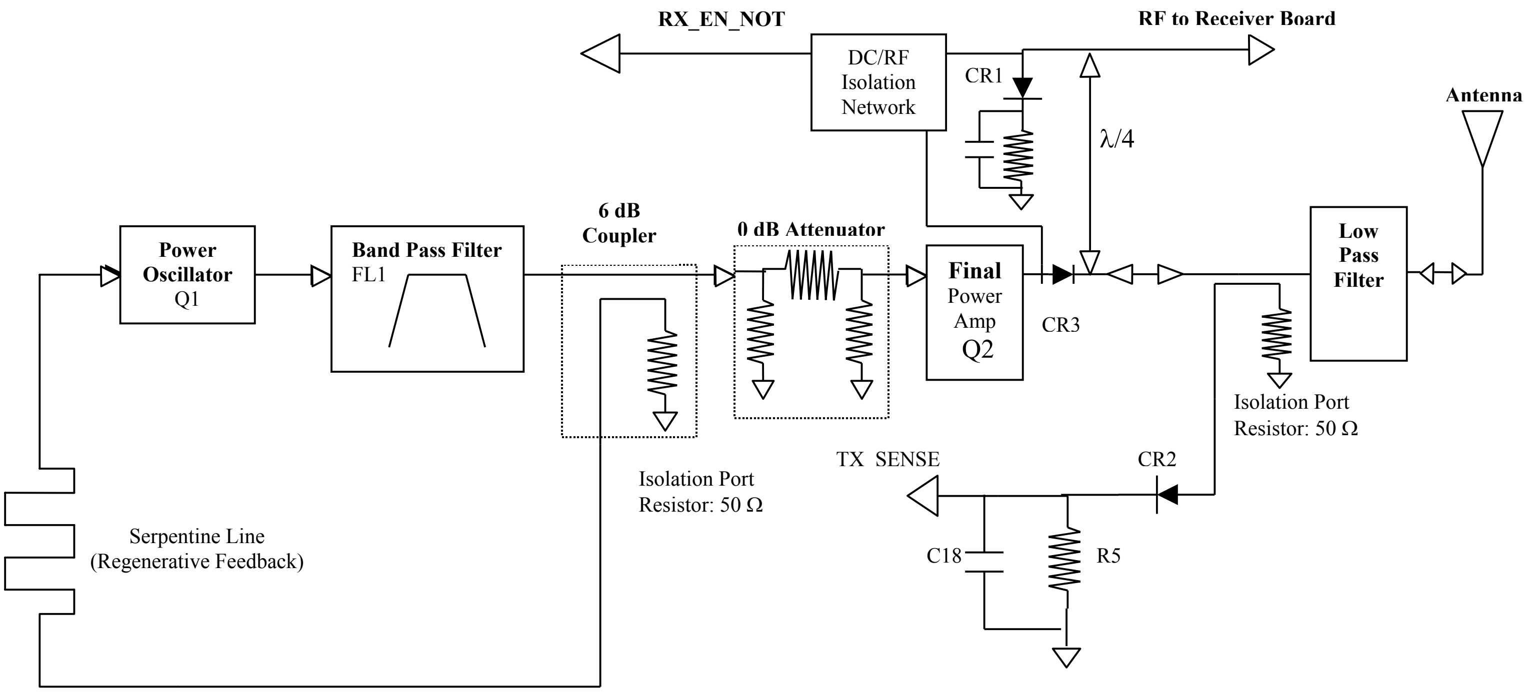
1.4 Emitter Modulator

Emitter modulator is a circuit that turns on the power oscillator, during the interval that the MOD_TRIG is high. When running the emitter modulator unloaded, the output is a negative 12 V pulse that occurs while MOD_TRIG is high. As in the collector modulator, I1 inverts the MOD_TRIG pulse and drives Q4 with a negative going pulse. Q4 is a small signal p-channel FET, which then saturates whenever MOD_TRIG is high. This results in a positive going pulse, which turns on Q6, a high current driver for the power oscillator. Transistor Q5 provides an active turnoff for Q6. The turnoff operation follows this sequence. When Q4 and Q6 are turned on, the gate and the source of Q5 are essentially the same voltage. Since Q5 is a p-channel FET, it is off when Q4 and Q6 are turned on. When the MOD_TRIG pulse goes low, V_{GS} for Q4 becomes zero volts and Q4 turns off. Simultaneously, V_G for Q5 goes to –12 volts, but V_S due to CR2 being reverse biased and the charge stored on C10, remains at +12 volts. Therefore, V_{GS} for Q5 right after the end the MOD_TRIG pulse is enough to turn Q5 on very hard. The charge on the gate of Q6 is the returned through Q5 and R11 to the –12 V supply. R 11 is an adjustable resistor that varies the discharge rate of Q5, which is used primarily to the RF output pulse width. Q5 stays on until it V_{GS} is less than two volts and CR5 prevents the gate of Q3006 from, going below –12 volts.

2.0 Transmitter Board

Reference schematic for the transmitter is KPN 002-08275-0040. A block diagram of the KT 73 transmitter is below in Figure 2. The transmitter board has three RF devices. The TX/RX switch, the power oscillator, and the power amplifier. The TX/RX switch routes RF signals received and transmitted through the antenna by way of the RF input/ output port to the receiver and transmitter. Q1 is a power amplifier used in an oscillator configuration. Q2 is a class C power amplifier providing 6 dB of gain.

Figure 2 Transmitter Block Diagram



2.1 Power Oscillator: In order for an amplifier to oscillate, it must have some of its output power fed back to its input at 360 degrees of phase shift. A classic oscillator definition is that an active device must have a loop gain of one and total phase shift of zero degrees. (360)

2.1.1 The active device is Q1 and the loop includes the output microstrip matching network, C6, FL1 in series with the entire Q1 output, 6 dB coupler, the 50 ohm phase matching network (serpentine line), C2, and the input matching network. The transistor has some insertion phase as well, but this is hard to quantify.

2.1.2 When the emitter modulator pulls low, with the Q1 collector at 50 volts, the circuit begins to oscillate.

2.1.3 The total length of the feedback path determines the frequency of the oscillation. The reason for the adjustable length 50 ohm line is to compensate for the variance in insertion phase between different transistors populating the Q1 part inventory. Even though C3 is used to adjust the frequency when the oscillator is close to 1090 MHz., decreasing the length of the 50 ohm line can raise the frequency higher, while lengthening the line makes oscillations lower in frequency. Smaller length loops can be added or removed for smaller frequency change and larger loops will change the frequency in greater increments.

2.2 Bandpass Filter FL1 is centered at 1090 MHz. with a 3 dB bandwidth of 10 MHz. The purpose of the filter is to keep the oscillator on frequency over temperature. As the temperature varies, so does the insertion phase through the transistor. This causes a change in oscillation frequency. Bandpass filter FL1 has a temperature coefficient of 15 PPM/degree. The variable capacitors change at 10 PPM/degree. The combined effect of the capacitors and the filter keep the frequency of oscillation within the +/- 1 MHz. limits.

2.3 The 6 dB Coupler, W1, is used to couple 25% of the FL1 RF output energy back to the input of Q1 oscillator to maintain oscillations. The oscillator puts out 130 Watts and is filtered by FL1. The insertion loss of FL1 is 1.45 dB leaving its output at 93 Watts. Coupled output being fed back is 23 Watts or 17% oscillator output. Through output is reduced 25% to 70 Watts. Loss in phase matching network is negligible.

2.4 The Zero dB Attenuator follows W1, but is currently shorted across R2, the series member of the network. Two shunt members, R3 and R4, make this a PI type design. The purpose is to reduce through output from W1 to the Power Amp to a level not exceeding the one dB compression point. At higher power inputs the power amplifier becomes saturated and the output pulse shape of the power amplifier becomes distorted.

2.5 Power Amplifier: The final amplifier is a class C RF amplifier with a gain of 6 dB. C4 and C7 are variable capacitors used to tune the matching networks to Q2 power transistor. Tuning C7 may also effect the frequency of the power oscillator due to loading of the power oscillator output. With 70 Watts driving the input, nominal power amp output is 280 Watts with 180 Watts reaching the antenna. 2 dB of insertion loss is dissipated from traveling up the coaxial cable hooking the output port of the unit to the antenna.

2.6 TX/RX Switch

The TX/RX switch works by biasing two surface mount diodes, CR1 and CR2, to route RF signals from the antenna to the receiver or to the antenna from the transmitter. The RLSI generates the RX_EN_NOT signal, which controls the TX/RX switch.

2.6.1 During the transmit cycle, the RX_EN_NOT line is set low by the RLSI. Integrated circuit I1 inverts the signal that then turns on Q7 and connects +5 V to E5. Applying +5 V to E5 turns on both CR1 and CR3. A low impedance path is now formed that directs all the energy from the transmitter output to the antenna while isolating the receiver with a high impedance path. CR3 is in series with the transmitter output passing the output power on a path to the antenna, while forward biased. CR1 is effectively shunted to RF ground a quarter wave length away at the receiver input. A shorted quarter wave length stub is effectively an open circuit path to the transmitter high power RF. The open circuit isolates the receiver path and protects the receiver because of the high impedance an open circuit present to the transmitter power.

2.6.2 During the receive cycle, the RX_EN_NOT line is set low by the RLSI. Integrated circuit I1 inverts the signal that then turns on Q8 and connects –12 V to E5. With –12 V on E5. A low impedance path is now formed which directs all energy from the antenna to the receiver input. R22 on the modulator board set the current through the diodes at 60 ma.

2.7 The Low Pass Filter is designed to reduce the level of the conducted harmonics of the 1090 MHz transmitter carrier. The filter is a seven-pole Chebyshev response with a 0.1 dB ripple. The 3 dB corner frequency is 1.3 GHz. The inductors are implemented using 26 AVG wire and the capacitors are ATC 500 volt chip capacitors. Silver plated housing with the wire in the center creates an air dielectric coax, whose characteristic impedance is 130 Ω. The coaxial cavity was created to have a high impedance line that would in turn create high Q inductors. The filter has 55 dB of attenuation at the second and third harmonics.