AUTOMATIC HF ANTENNA TUNER

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Abstract - *Any tuner circuit consist of inductors (L) and capacitors(C). The manual tuner usually provides an SWR meter to indicate tuning and constantly monitors the match between transreceiver and antenna. To accomplish this, the tuner will have several controls and dials (knobs) used to set and fine tune it. This can add complexity to the usage that some find objectionable. As the user switches bands, re-tuning is necessary. This can lead to quite a bit of adjusting if one is "band hopping" to find that certain contact. Automatic tuners are much faster at tuning, especially with dramatic changes (such as moving between bands or from edge to edge within a band) and typically complete their tuning in well under a second. They also remember prior tuning settings, which is a big reason why they can complete their tuning so quickly. A directional wattmeter provides forward and reflected power values to an Atmel ATmega32 microcontroller, which calculates VSWR and adjusts a capacitor -inductor matching network using stepper motors to reduce VSWR.*

***Key Words*: Automatic tuner, SWR, Directional Wattmeter, transreceiver.**

1. INTRODUCTION:

Two-way communications using 3 MHz to 30 MHz, high-frequency (HF) radio, also known as shortwave radio, offers worldwide coverage with no required infrastructure between stations, making it useful for emergency communications. Worldwide range is possible due to HF radio wave refraction in the ionosphere known as skywave propagation. The optimum frequency for long distance skywave propagation changes with time of day due to the sun's influence on the ionosphere. An Antenna tuner, a matchbox, transmatch, antenna tuning unit (ATU), antenna coupler, or feedline coupler is a device connected between a transreceiver and its antenna to improve power transfer between them by matching the impedance of the transreceiver to the antenna's feedline. Antenna tuners are particularly important for use with transmitters. Transmitters feed power into a load, for which the transmitter is optimally designed for power output, efficiency, and low distortion. Due to improper tuning of the antenna/feedline combination the power output will change, distortion may occur and the transreceiver may overheat. The automatic tuner is generally easier to use than a manual one, providing operator convenience. Rather than adjusting knobs to achieve a match, the automatic circuitry progresses through a set of "trial and error" settings seeking the best match. This takes only a few seconds the first time that particular frequency is used with the tuner. Most modern antenna tuners have memories that retain adjustment settings for given frequencies and can recall these settings instantly. An antenna tuner can render the antenna resonant to the transmitter and eliminate reflected power by providing compensation for the impedance mismatch.

2. Block diagram:

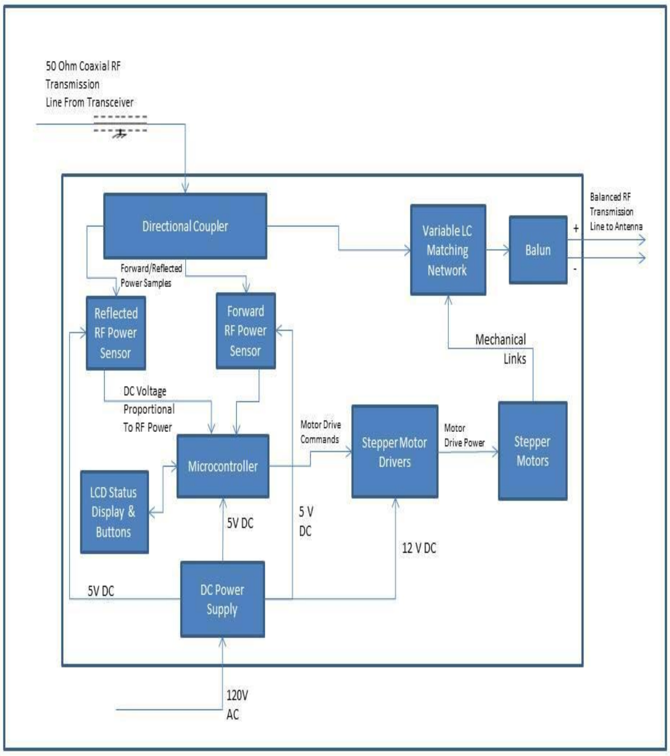

Fig : Block Diagram

2.1. Forward/Reflected RF Power Sensor:

Produces two DC voltage outputs: one proportional to the forward RF power and one proportional to reflected RF power.

2.2. Directional Coupler:

Provides 30dB reduced samples of the forward and reflected RF power to allow RF power sensor power measurement

2.3. Balun:

A Balun is a transformer that converts an unbalanced line to a balanced line.

2.4. Variable LC Matching Network:

The LC Matching network is a shunt variable inductor and a series variable capacitor that each provide the necessary reactance to achieve an impedance match. A single pole, double throw RF switch places the shunt inductor on either side of the capacitor to match a wider range of impedances.

2.5. Microcontroller:

The microcontroller measures DC voltage from the RF power meter and issues motor drive commands to adjust the LC network for an impedance match. It also provides serial data to display RF power level and tuning status

2.6. DC Power Supply:

Converts 120 V AC to 12 V and 5 V DC power for the circuitry and stepper motors.

2.7. Stepper Motor Drivers:

Provides motor power based on commands received from the microcontroller.

2.8. Stepper Motors:

There are three stepper motors: The L and C motors adjust the variable inductor and capacitor, and a linear actuator motor controls the RF switch in the matching network

3. COMPONENT USED:

The components used to build setup are as follows:

1. SWR Meter,
2. Impedance Matching System,
4. Stepper motor,
5. Analog to digital converter,
6. Microcontroller,
7. DC Power Supply.

3.1. SWR Meter:

A SWR Meter (directional coupler) is an RF power measurement device with four ports: RF input, RF output, forward coupled (or sampled), and reflected (or reverse) coupled. A directional coupler samples a portion (coupling factor) of RF power in the forward and reverse directions. The coupling factor (separate values for forward and reverse directions) is the ratio of actual to sampled RF power. The RF input and output ports are connected by a main (through) line and the forward and reflected coupled ports are connected by a coupled line. A portion of the main line RF power is diverted to the coupled line where it is attenuated by a fixed value known as the coupling factor (ratio of actual to sampled RF power). The coupling factor is high, ~1000 or 30 dB, to minimize main line power loss. The forward coupled port power is coupled in phase with the main line forward power and out of phase with main line reflected power, further attenuating reflected power by a factor known as directivity. The opposite case is true for the reflected coupled port. The directivity is the power ratio of the forward to reflected coupled ports with the through port terminated in a matched (Γ = 0) load. Directivity is ideally infinite since there should be no reflected coupled power for a matched load at the through port. The directional coupler allows transmission line forward and reflected power measurement using sensitive low power electronics while minimizing main line power loss.

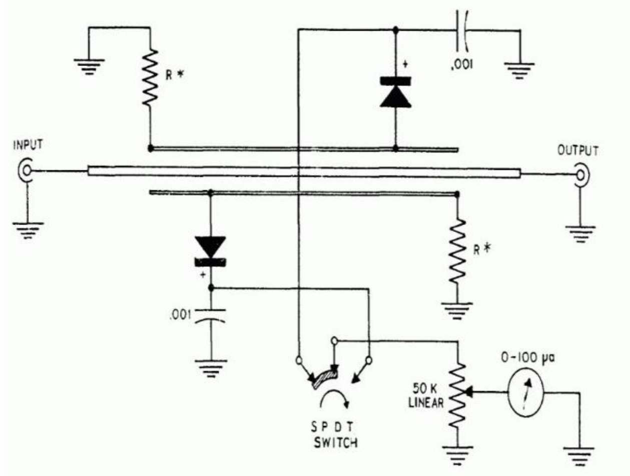

Fig-1: SWR meter

Diode: A079 (detector)
Resistance: 1kΩ
meter: Analog meter

3.2. Impedance Matching System (IMS) :

The Impedance Matching network is a shunt variable inductor and a series variable capacitor that each provide the necessary reactance to achieve an impedance match.

Table -1: IMS System Level Functionality Table

MODULE:	Impedance Matching System (IMS)
INPUT	1. Power: 120 V AC at less than 10 A 2. 50 Ω Coaxial Cable from Transceiver: Carries 3.5 to 30 MHz transmit signal from the Transceiver to the IMS. 3. User pushbuttons
OUTPUT	1. Balanced Transmission Line to Antenna: Carries transmit signal from the IMS to the antenna. 2. Status Indicators: An LCD provides user with current value of Voltage Standing Wave Ratio (VSWR)., forward and reflected power, inductor & capacitor relative positions (i.e. minimum And maximum inductance or capacitance), and RF Switch Position.
FUNCTIONALITY	Senses greater than 1.5:1 VSWR during transmit and adjusts internal reactance to match antenna transmission line impedance to the 50 Ω transceiver coaxial connection

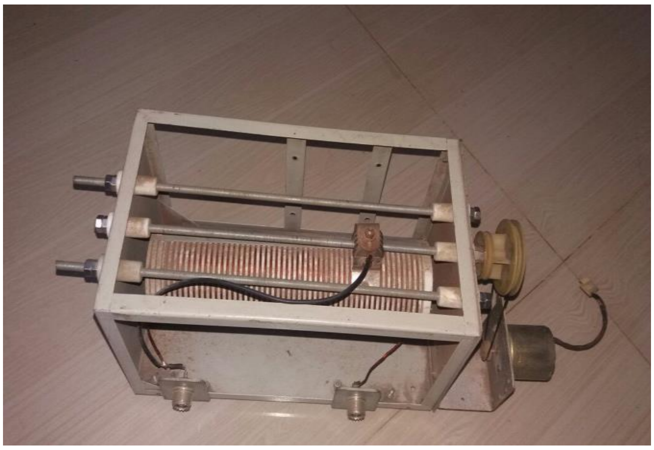

Fig-2: Variable Inductor

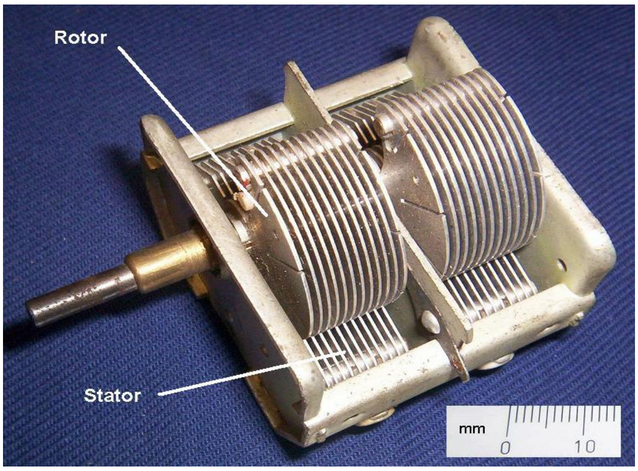

Fig-3: Dual Air Gang Capacitor

3.3. Stepper Motor:

Rotate the variable capacitor and inductor using the stepper motors. Rotation will not occur if the required torque exceeds the 125 oz/inch motor rating. A stepper motor or step motor or stepping motor is a brushless motor dc motor that divides a full rotation into number of equal steps. The motor position can then be commanded to move and hold at one of these steps without any position sensor for feedback. Microcontroller interfacing requires three output pins to control three functions: Step, Dir, and Enable. "Enable" turns on the driver and applies motor drive current. "Step" rotates the motor one step for each rising edge. "Dir" defines "Step" rotation direction; clockwise or counter clockwise. Driver IC is required to provide 12V input to run stepper motor.

3.4. Microcontroller:

The microcontroller measures DC voltage from the RF power meter and issues motor drive commands to adjust the LC network for an impedance match. It also provides serial data to display RF power level and tuning status. Commands are send to drive stepper motor by using AT 89S51.

3.5. Analog to digital converter:

There are many methods to convert analog signals to digital signals. The objective to use analog to digital converter is to secure information by transmitting analog signals to digital numbers so microcontroller can read them easily. There are many ADC converters like ADC0801, ADC0802, ADC0803, ADC0804 and ADC080. We are using ADC0804 with 0 to 5V analog input voltage. It has single analog input and 8-digital output. Compatible with microcontrollers, access time is 135nsec. Logic inputs and outputs meet both MOS and TTL voltage level specifications.

3.6. DC Power Supply:

Four devices require power: the microcontroller, the power sensors, the LCD, and the stepper motor drivers. The stepper motor drivers require 12 ± 1 V at 1 A. AT 89S51 microcontroller require 4.4-5.5v supply range with maximum current 200mA.The supply current capability is increased to 1 A for the 5 V supply and 2 A for the 12 V supply for improved reliability.

4. Design analysis:

In practice, operators typically use antenna tuners to match antennas for frequencies above the resonant frequency.

4.1. Voltage amplitude increases with reflection coefficient magnitude, |Γ|, between the antenna and transmission line and therefore increased voltage standing wave ratio (VSWR). Superposition of forward and reflected waves along the transmission line produces standing waves resulting in maximum and minimum voltage amplitude locations. VSWR is the ratio of the maximum to minimum transmission line voltage amplitude.

$$\Gamma = \frac{(Z_{load} - Z_o)}{(Z_{load} + Z_o)} \quad (1)$$

where Zload is the complex antenna (load) impedance and Zo is the transmission line characteristic impedance. Zo is typically assumed purely real for commercial transmission lines.

$$SWR = \frac{|V_{max}|}{|V_{min}|} = \frac{1+|\Gamma|}{1-|\Gamma|} \quad (2)$$

4.2. SWR can also be calculated from forward and reflected power using equation (3). The IMS employs forward and reflected power measurements to calculate SWR.

$$SWR = \frac{1+\sqrt{(Pr/Pf)}}{1-\sqrt{(Pr/Pf)}} \quad (3)$$

4.3. The capacitor used is a variable air gang capacitor with a value ranging from 0-285pF.

4.4. Power supply of 12V 2A is required to drive stepper motor and 5V 1A is required for microcontroller.

5. Testing:

Test 1:

The directional coupler should not present greater than 1.5:1 SWR at its RF input with its outputs terminated in 50 Ω (Γ = 0) loads. Measure RF input SWR using a vector network analyzer over the 3.5 to 30 MHz frequency range with all outputs terminated in 50 Ω.

Test 2:

The coupling factor (ratio of actual to sampled RF power) should be 30±1 dB . Connect an RF signal generator set to 0 dBm to the RF input port and measure the forward coupled port output power using a spectrum analyzer to determine the coupling factor. Ideally, the coupling factor should not vary by more than 1 dB from 3.5 to 30 MHz

Test 3:

Minimum directivity, equation below, is 28 dB. Connect an RF signal generator set to 0 dBm to the RF input port and terminate the RF output port in 50 Ω. Measure the RF power at the forward and reflected coupled ports using a analyzer.
Directivity = [fwd coupled pwr] - [refl coupled pwr] (4)
Minimum directivity is 28 dB over 3.5 to 30 MHz range.

Test 4:

Connect a 50 Ω dummy load to the matching network output and a 3.5-30 MHz transmitter and SWR meter to the input. Manually tune the matching network from 3.5 to 30 MHz. The matching network should achieve maximum 1.5 SWR matching from 3.5 to 30 MHz.

Fig-4: Final test

3. CONCLUSION:

In the today's world while setting up wireless communication system impedance matching between transreceiver and antenna manually is slow though it is simple and cheaper. Time required for manual tuning is reduced by using automatic tuning which makes tuning fast .Transreceiver is protected by regulating VSWR using directional wattmeter.

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