directional couplers that sample the forward and reflected power at the transmitter output. For those transmitters without a remote output power sample (or those stations using combined transmitters), a transmission line directional coupler with an associated wattmeter (with remote sample) can be added. NTSC television transmitter output power meters include a peak detector circuit, since the RMS output power varies substantially with picture content. The NTSC peak amplitude (tip of sync) should be a constant power. Different power measurement techniques are used with the newly adopted digital television standard.

The dc output of the reflectometer has a relatively high source impedance and is easily loaded. Many transmitters include isolation circuitry so the remote or extension meter does not load the directional coupler, causing inaccurate indications on the transmitter front panel meter.

The sample voltage out of a directional coupler is proportional to the square root of the power (directly proportional to the voltage or current), except at very low powers, where the diode knee voltage again causes additional nonlinearities. The output power meter on most transmitters is a mechanical meter with a nonlinear scale, allowing it to read output power directly. An analog remote meter can also use the same scale, allowing direct reading of the transmitter output power. Digital meters, however, generally use a linear A/D converter. Getting an accurate remote indication involves squaring the sample voltage either before or after the A/D converter. The sample voltage can be squared prior to the A/D using an analog multiplier (or balanced modulator) and tying the two inputs together (multiplying the sample voltage by itself). Devices that handle this analog squaring are often called *power to linear converters*.

The sample voltage can also be squared after the A/D converter. This may be done by giving the transmitter operator a chart (indicated power versus actual power). Finally, most microprocessor based remote controls make this calculation automatically.

AM POWER SAMPLING

AM stations generally determine power by measuring the RF current into the antenna system. For nondirectional stations, this is the base current of a series fed antenna or the feedwire current of a shunt fed antenna. A directional station measures the current into the common point of the array. In each case, the measured current is squared and multiplied by the resistance (base, feed wire or common point) to arrive at the power into the antenna. Section 73.51(a)(1) of the FCC Rules also permits the use of direct reading power meters that measure the voltage, current and phase relationship between them to determine the power, but these meters are rare.

RF currents have traditionally been measured with thermocouple meters, which measure the true RMS current. Remote thermocouple meters are available, but suffer from nonlinearity between the RF current and the sample voltage. Further, when an AM transmitter is modulated, the RMS current into the antenna increases (corresponding with the addition of power to the AM sidebands). The FCC places limits on the unmodulated antenna current. Having the antenna current indication vary substantially with modulation would require checking the antenna current without modulation. For these reasons, diode meters are now generally used for remote RF current indications.

Diode meters utilize an RF current sensing transformer to develop a dc voltage that is proportional to the RF current. The dc sample is obtained by running the rectified RF through a low pass filter that removes the ac components (RF and audio). Ideally, the dc component of the rectified RF is constant, since the transmitter ac couples the audio into the final amplifier (using typical modulation techniques). The sample voltage will be the same with or without modulation, allowing measurement of the unmodulated antenna current without interrupting modulation. Again, there are potential nonlinearities due to diode knee voltages. However, these may be overcome by placing the current sense transformer terminating resistor after the rectifier, as was done in the tower light sensor previously described. Other techniques are available to eliminate this nonlinearity. These include developing a bias voltage to get over the knee and the use of zero crossing driven FET switches (similar to a synchronous rectifier).

A well designed diode meter (such as the Delta TCA series) also serves well as the local antenna current meter. These meters provide a local indication and a sample voltage suitable for driving remote metering.

In practice, the indication of a diode type RF ammeter will vary with modulation. This is generally due to less than perfect carrier amplitude regulation (carrier shift) in the transmitter. Often the transmitter high voltage power supply is loaded by the modulators as the modulation level is increased, decreasing the high voltage available for the final amplifier. This can cause a decrease in the indicated antenna current. Variations in the antenna impedance with frequency may also cause carrier shift, as the various sideband frequencies see a varying load impedance. If these variations in indicated antenna current are excessive (remote antenna current meters are required to agree with the local meter within 2% [Section 73.57(d)]), the readings would have to be taken without modulation, or perhaps some electrical compensation could be added (see *Carrier Shift Compensation*).

Some stations take a sample of the RF voltage at the antenna input (base, feed wire or common point) and calibrate the remote indication to agree with the local ammeter. Assuming the impedance of the antenna is constant, then the RF voltage will indeed be proportional to the current. This approach uses the antenna itself as a *current to voltage converter*.

Finally, directional stations are equipped with a very high quality RF detector circuit in their antenna monitor. Stations that operate nondirectional some portion of the time may use the indication of the antenna monitor current sample for the nondirectional tower as a remote base current sample. The actual RF sample is typically from an RF current transformer at the base of the tower or a current sampling loop part way up the tower. Stations can also add a current sense transformer just prior to the common point meter. This transformer can drive the antenna monitor to give a remote sample of the common point current.

Carrier Shift Compensation

The circuit of Figure 4.7-8 may be added between a Delta TCA RF ammeter and a remote control (input resistance of 1 M or MΩ greater) to compensate for variations in indicated antenna current due to carrier amplitude shift with modulation. Figure 4.7-9 shows the remote sample voltage out of a Delta TCA2OEXR with modulation. Normally, the ac component (due to modulation) is removed by a low pass filter in the remote control or the *mechanical low pass filter* created by the movement of mass in a meter movement. If R2 is set to the center of its range, the circuit of Figure 4.7-8 forms a low pass filter (Fh = .034 Hz). The output voltage will be the dc component of the input, regardless of any ac component (due to modulation). If, during modulation, the dc component drops (due to carrier shift), the dc output voltage will drop. If, however, the wiper of R2 is moved towards Dl, Cl will tend to charge to the peak input voltage instead of the average voltage. If the output voltage without modulation is measured (remote control calibrated without modulation), then R2 adjusted for the same indication with modulation, most of the effects of carrier shift can be removed. Testing of the circuit on a 5 kW plate modulated transmitter operating into a three tower directional array reduced variations in indicated common point current from ±1.2% to ±0.1%.

Note that the circuit must not be loaded by the remote metering circuitry. If a low resistance (less than 1M or MΩ) is to be driven, a standard operational amplifier voltage follower circuit should be added between the carrier shift compensator and the remote metering system.

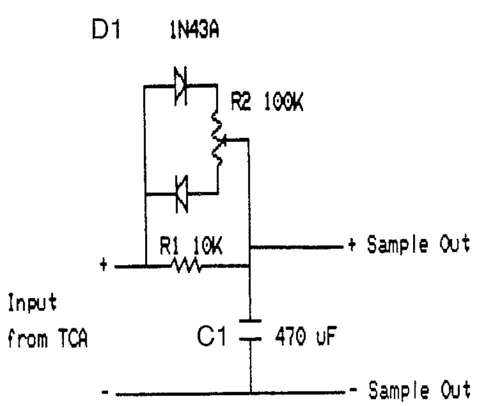

Figure 4.7-8. Remote ammeter carrier shift compensator.

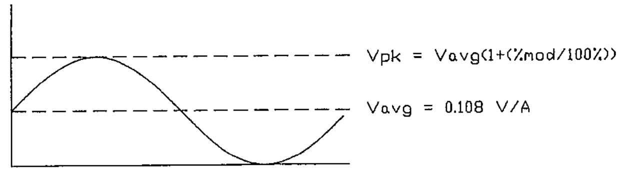

Figure 4.7-9. Remote sampler output waveform of Delta TCA20EXR. Note that Varg will typically decrease with modulation due to carrier shift. Vpk increases with modulation.

DIRECTIONAL ANTENNA MONITOR

AM radio stations with directional antenna systems must have an antenna monitor to verify the proper operation of the antenna system when operated in a directional mode. The indications of a directional antenna monitor may also drive remote meters when designed for such use and when authorized by the FCC (Section 73.53(a)(9)). Most antenna monitors require a tower select input and usually a pattern select input in order to measure the amplitude (or ratio) and phase of the selected tower, though some more recent monitors provide continuous outputs of all samples. Additional difficulties are caused by the necessity to properly indicate phase relationships that may be positive, negative or very close to 0°. In extension metering systems, the tower select controls can be extended to the metering point, allowing the operator to select which tower the monitor will measure.

Most (though not all) antenna monitors use one or two amplitude detectors and one phase detector. This technique requires that the detector circuitry be shared among several towers through the use of an RF multiplexer which selects the desired tower input samples. Monitors with two amplitude detectors leave one connected to the reference tower at all times. The other (or only) amplitude detector is switched between the RF samples from the various towers in the antenna system. One input of the phase detector is also constantly connected to the reference tower. The other input of the phase detector follows the amplitude detector, connecting to one tower sample at a time. When a tower is selected on such an antenna monitor, the response time of the RF multiplexer and the settling time of the detection circuitry prevent an accurate indication from being immediately available. At least one antenna monitor avoids this problem by providing complete detector circuitry for each tower input sample. This approach eliminates the need for tower input selection and can provide continuous indications of all ratios and phases to remote control equipment.

In remote control applications, when tower select inputs are required, the control outputs of the remote control system are typically used to drive the tower select inputs of the antenna monitor. A fairly common practice has been to assign a tower to a channel, then use the *raise* control to read the phase and the *lower* control to read the loop current or ratio. This technique, however, requires interface circuitry between the re-