# COMMON MICROWAVE RADIO
# OVERALL TD SYSTEM TEST
# RF COMBINER

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## 1. GENERAL

**1.01** This section describes the RF combiner used with TD space diversity radio systems. Included are testing and maintenance sections.

***Caution: These tests must be performed on an out-of-service basis. Obtain a release from the radio section control office and proceed as directed by local practices.***

**1.02** Whenever this section is reissued, the reason for reissue will be stated in this paragraph.

**1.03** Radio hops in a normal frequency diversity protection switching section may also be equipped for space diversity operation at the receiver. Space diversity systems employ two receive antennas mounted some distance from one another, so that slightly different air paths are used. For these arrangements, the radio receiver must be equipped with either an RF switch to switch the receiver input between the main and the space diversity antenna, or with an RF combiner which is connected to both antennas and provides a single (combined) input to the receiver. Each plan has certain advantages and disadvantages. RF switching arrangements can be technically simple, but switching may cause phase hits and/or level changes affecting transmission. Combining signals from diverse radio paths requires dynamic phase regulation for satisfactory transmission. Until recently, only RF switching has been used because effective dynamic phase regulation has been beyond the state of the art.

**1.04** RF combining for TD-type radio bays can now be provided by means of the 713A or B IC (RF combiner) and the associated 95A control unit (SD-51899-01). These units are mounted as an assembly on the channel separating network at the top of the TD-2 bay or between the circulator and the bandpass filter assemblies in the TD-3( ) bays.

## 2. GENERAL DESCRIPTION

### A. Equipment Features

**2.01** The RF combiner, shown in Fig. 1, consists of two major modules. The RF unit, coded 713( ) IC is a 3-port waveguide housing containing in the space diversity antenna path, an RF amplifier, pair of phase shifting networks, and a phase modulator. A 3-dB coupler is common to both paths. The second module, coded 95A control unit, mounts on the side of the RF unit and contains two printed circuit boards, an RF amplifier ON/OFF switch, a main amplifier selector switch, an alarm relay, a red LED alarm indicator, and a pair of AGC voltage terminals.

**2.02** The RF module bridges the outputs of the main and the diversity paths of the receiver channel separating networks. The combined output is connected to the normal input of the receiver. The 713( ) IC is manufactured in two codes: the 713A IC covers the frequency range from 3.7 GHz to 3.94 GHz

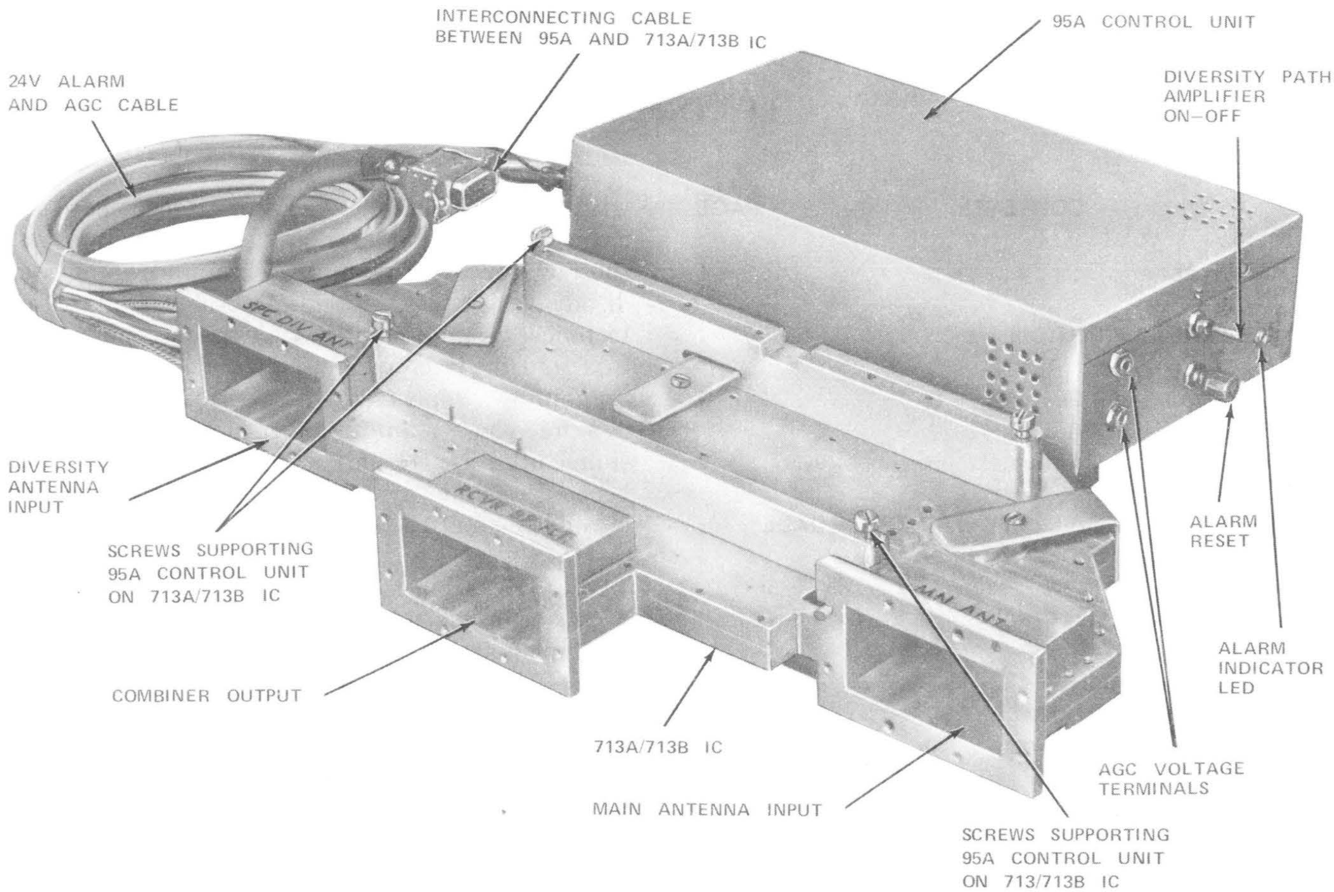


**Fig. 1—Space Diversity RF Combiner**

and the 713B IC covers the frequency range from 3.94 GHz to 4.2 GHz.

**2.03** The 95A control unit mounts on the side of the 713( ) IC and contains two solid-state circuit boards and an alarm relay. The faceplate of the control module displays the alarm indicator LED, the diversity path RF amplifier ON/OFF switch, an alarm reset pushbutton, a rotary switch that must be set to the type of IF main amplifier being used, and a pair of AGC voltage monitoring terminals. The rear panel of the control unit accepts two connecting cables. One cable provides the −24 volt office battery voltage, the connections to the office alarm system, and the AGC voltage input from the IF main amplifier. The second cable interconnects the RF combiner with the control unit to provide the bias voltages for the RF amplifier, the phase control signals for the phase shifter and phase stepper, and the drive for the phase modulator.

### B. Circuit Description

**2.04** A basic requirement of the RF combiner is that the electrically shorter antenna system must be built out so that the delay difference between the main and diversity antenna systems at the output of the combiner is 2 nanoseconds or less. This is generally done by adding waveguide to the shorter run.

**2.05** The signal from the main antennas passes through the combiner without any effect other than the 3-dB loss in the coupler. The diversity signal passes through the components of the combiner which are shown in Fig. 2.

**2.06** The RF amplifier compensates for the losses in the other components in the diversity signal

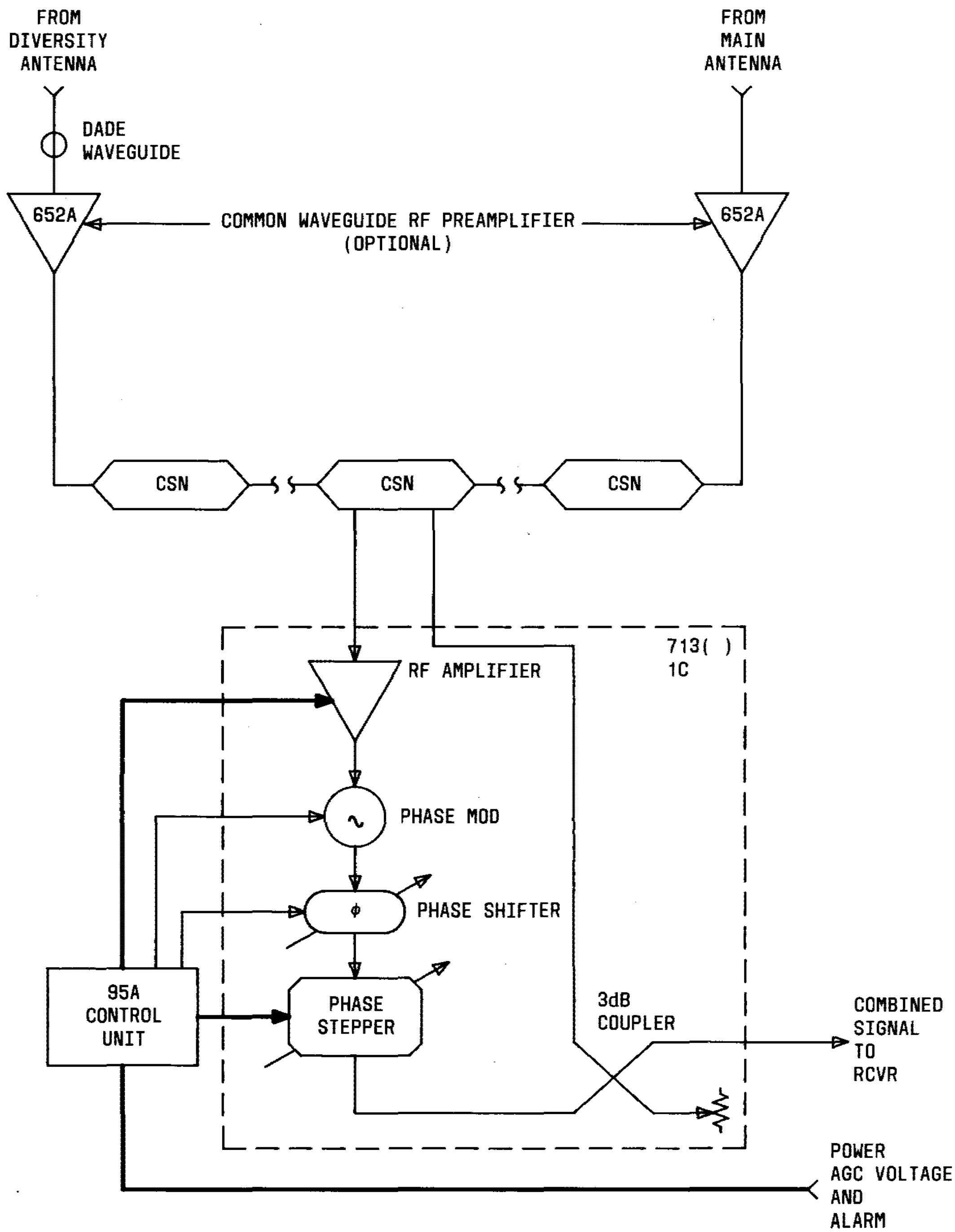


Fig. 2—RF Combiner Schematic Diagram

path. The signal from the diversity antenna is phase modulated at a 10-Hz rate to produce a 10-Hz AM component on the combined signal and on the AGC voltage of the IF main amplifier. This 10-Hz component is recovered in the control unit to produce the phase control signal which is applied to the phase shifter—phase stepper. The 10-Hz AM component on the combined signal is removed by the AGC action of the IF main amplifier and does not appear in the IF output signal of the receiver. The phase stepper operates in ±90 degree steps while the phase shifter has a slightly greater than 90-degree range. The two units, operating in tandem, have the capacity to make an infinite number of dynamic phase corrections over the full ±360 degree range.

**2.07** There are no maintenance adjustments on either the RF combiner or the 95A control unit. The front panel of the control unit displays an ON/OFF switch which controls the power to the RF amplifier. The level of the diversity signal is reduced about 25 dB when the RF amplifier is not operating. The alarm indicator LED and the alarm reset button are also located on the front panel of the 95A unit. An alarm indication will result when any one of three monitored conditions is out of limits for at least 6 seconds:

(a) RF amplifier bias voltage

(b) 10-Hz drive to the phase modulator

(c) Phase-lock component of the AGC voltage.

The power to the RF amplifier is disconnected whenever an alarm condition exists. The alarm relay is a locking relay which must be manually released.

## 3. TESTS—SPACE DIVERSITY WAVEGUIDE DADE

**3.01** Space diversity operation with the RF combiner requires that the signal from the main antenna and the signal from the diversity antenna reach the RF combiner output within 2 nanoseconds of one another so that dynamic phase equalization of the two may be accomplished. The method of meeting the requirement, known as differential absolute delay equalization (DADE), is to add or remove waveguide until the two runs have approximately equal RF transmission lengths. It is a common engineering practice to design the diversity waveguide run to provide an access point where DADEing sections may be added or removed.

The engineering information necessary to calculate the probable waveguide lengths is contained in SD-51905-01. The following procedure should be used to complete the final DADEing.

## CHART 1

### TESTS
### RF WAVEGUIDE DADE
### TRANSMITTING AND RECEIVING STATIONS

***Note:*** The DADEing procedure uses a signal transmitted over an air path which may be subject to minor changes almost constantly, yet the differences in meter indications used to determine the proper DADE are in the .01- to .05-dB range. The time period for DADEing operations should be selected to minimize the effect of atmospheric conditions. The operation should be staffed so that the time required to complete a series of measurements will be as low as practical and the cycle of initial measurements should be completed at least twice prior to making changes in the waveguide system.

CHART 1 (Contd)

| STEP | PROCEDURE |
|---|---|
| | **Transmitting Station** |
| 1 | Connect the 70-MHz output of the FM transmitter to the input of the channel under test. Use IF pads to obtain the correct power at the point of connection. |
| 2 | Apply a 9.5-MHz signal at −30 dBm to the baseband input to the FM transmitter. |
| | **Receiving Station** |
| 3 | Connect the output of the IF main amplifier through a 17-dB (TD-2, TD-3D) or 8-dB (TD-3, TD-3A) pad to the IF input of the FM receiver. |
| 4 | Connect the selective level meter to the baseband output of the FM receiver, tune it for a peak reading at 9.5 MHz, and record the amplitude measured. This is the 9.5-MHz tone amplitude with the combiner operating. |
| 5 | On the diversity combiner 95A control unit, turn the DIVERSITY PATH AMPLIFIER switch to the OFF position. |
| 6 | In the diversity waveguide run where the fine DADEing waveguide assembly (per L-848589) is located, remove the 180-degree bend and install a shorting plate or termination on the open waveguide connected to the bay lineup. |
| 7 | Record the selective level meter indication of the 9.5-MHz signal. This is the 9.5-MHz amplitude with the combiner not operating. |
| 8 | Calculate the change in the tone amplitude by subtracting the indication in Step 4 from the indication in Step 7. This change is a measure of the difference in length of the two waveguide runs. If the change is 1 dB or less, go to Step 10. If the change is greater than 1 dB, continue with Step 9. |
| 9 | If the change calculated in Step 8 is greater than 1 dB, add a total of 12 feet of waveguide in the fine DADEing waveguide assembly and repeat Steps 4 through 8.<br>(a) If the change is now smaller, the diversity waveguide run was shorter and the remaining difference can be calculated by continuing with Step 12.<br>(b) If the change increased, the regular waveguide run was shorter than the diversity run. In this case, the additional 12 feet of waveguide must be removed from the diversity run and either the diversity run must be made shorter, or the regular run must be made longer, by the waveguide length calculated in Step 12. Proceed to Step 12. |

CHART 1 (Contd)

10 The change calculated in Step 8 can be used to determine the difference in length between the two waveguide runs. However, which run is longer is not defined. To determine which is shorter, record the meter indication of the 9.5-MHz tone with the shorting plate on the diversity run (i.e., combiner not operating). Remove the shorting plate and add 2 feet of waveguide to the fine DADEing waveguide assembly, reconnect the diversity run to the bay lineup, and turn the DIVERSITY PATH AMPLIFIER switch on the 95A control unit to the ON position.

11 Record the 9.5-MHz amplitude and subtract it from the amplitude recorded in Step 10.

(a) If the change here is less than the change calculated in Step 8, then the diversity run is shorter than the regular run.

(b) If the change here is greater than the change calculated in Step 8, then the regular run is shorter than the diversity run.

(c) If the change here is the same as the change calculated in Step 8, then the diversity run was slightly shorter originally and, after the addition of 2 feet to the fine DADEing assembly, is now slightly longer.

12 Using Table A and the amplitude change calculated in Step 8 or Step 9, determine the length of waveguide to add to whichever waveguide run was indicated as shorter in Step 11 or Step 9.

***Note:*** Generally, the diversity waveguide run will be shorter and the DADE waveguide will be added to it. Where the regular waveguide run is shorter, either the DADE waveguide must be added to it (with the attendant service problems in breaking open a working waveguide run) or the diversity run can be reengineered to make it shorter. (See SD-51905-01.)

13 For TD-3 type stations, continue with Step 14. For TD-2 type stations, go to Step 15.

TABLE A

| 9.5-MHz TONE AMPLITUDE CHANGE (dB) | FEET OF WAVEGUIDE TO ADD |
|---|---|
| 0 | 0 |
| 0.05 | 3 |
| 0.10 | 4 |
| 0.15 | 5 |
| 0.25 | 6 |
| 0.35 | 7 |
| 0.45 | 8 |
| 0.55 | 9 |
| 0.70 | 10 |
| 0.85 | 11 |
| 1.00 | 12 |

**CHART 1 (Contd)**

14 After the DADE waveguide has been added, Steps 4 through 8 should be repeated to confirm the correctness of the DADE. What is desired is a change in the amplitude of the 9.5-MHz signal no greater than 0.1 dB when the diversity antenna signal is removed or added.

15 For TD-2 type stations where the diversity and regular waveguide runs enter opposite ends of the bay lineup, there is only one point in the lineup that can be exactly DADEed. To prevent excessive misDADEing for the end bays, the bay lineup should be DADEed to the center of the bay lineup, i.e., halfway between channels 3 and 4 (or 9 and 10). The DADE will vary across the bay lineup, being best for the center bays and somewhat degraded, but acceptable, for the end bays. The measurement made in the preceding steps results in perfect DADEing to the bay in the lineup where the DADE measurement has been made. That measurement now has to be adjusted to shift the DADE point to the center of the lineup. The amount of adjustment depends on the position in the bay lineup of the bay that was measured. In addition, the sign of the adjustment (i.e., more or less waveguide) depends on whether the measured bay is before or after the center of the lineup, and whether the diversity or regular run is shorter. Table B gives the amount of waveguide that should be algebraically added to the calculated DADE waveguide. If the final result is a positive number, the shorter waveguide run, as determined in Step 11, must be lengthened by this additional amount. If the final result is a negative number, the shorter waveguide run must be shortened by this amount.

*Example 1:*

| | |
|---|---|
| Measured Channel | Ch. 1 |
| DADE Waveguide (Step 10) | 8 Feet |
| Shorter Run (Step 13) | Diversity |
| Correction (Table B) | +10 |
| Total DADE | 8 + 10 = 18 feet added to Diversity |

*Example 2:*

| | |
|---|---|
| Measured Channel | Ch. 2 |
| DADE Waveguide (Step 10) | 4 Feet |
| Shorter Run (Step 13) | Regular |
| Correction (Table B) | -6 |
| Total DADE | 4 − 6 = −2 feet |

The −2 feet result shows that the regular waveguide run must be shortened by 2 feet. As an alternative, the diversity waveguide run may be lengthened by 2 feet to obtain the same result.

CHART 1 (Contd)

16 After the DADE waveguide has been added in TD-2 type stations, a check should be made to ensure that DADE calculations and corrections have been performed properly. A measurement as shown in Steps 4 through 8 should be made on two channels symmetrically spaced about the center of the lineup and as close to the end of the lineup as possible (i.e., 1 and 6, 2 and 5). If the DADEing is correct, the change in amplitude of the 9.5-MHz signal on the two channels should be equal within 0.1 dB. If not, the DADE measurement, calculation, and correction should be checked for possible errors and corrected if necesssary.

TABLE B

| MEASURED CHANNEL | WAVEGUIDE ADJUSTMENT IN FEET | |
|---|---|---|
| | IF DIV. IS SHORTER | IF REG. IS SHORTER |
| 1 or 7 | +10 | -10 |
| 2 or 8 | +6 | -6 |
| 3 or 9 | +2 | -2 |
| 4 or 10 | -2 | +2 |
| 5 or 11 | -6 | +6 |
| 6 or 12 | -10 | +10 |

## 4. DETAILED TESTS

**4.01** These tests may be used to determine the operating condition of the RF combiner.

CHART 2

DETAILED TEST
RF COMBINER

***Note:*** This test must be performed on an out-of-service basis and during nonfading conditions.

**CHART 2 (Contd)**

| STEP | PROCEDURE |
|---|---|
| | **Receiving Station** |
| 1 | Connect a 26A split pad and IF power meter in the normal circuit at the IF preamplifier output as shown in Fig. 3. |
| 2 | Terminate the output of the IF main amplifier. |
| 3 | After a few seconds, note the IF power meter indication.<br><br>***Requirement:*** A relatively constant power of −6.0 dBm ±1.0 dB for systems without the 652A waveguide RF preamplifier or −3.0 dBm ±1.0 dB for systems with the 652A unit.<br><br>If this requirement is not met, the gain of the receiver modulator—IF preamplifier is not correct. This test procedure depends on a change in power rather than the absolute power. If the present indication is not fluctuating, this procedure may be completed. A check of the receiver modulator—IF preamplifier gain should be made as soon as possible using the applicable BSP. |
| 4 | Operate the main amplifier AGC-MAN switch to the MAN position.<br><br>***Requirement:*** The IF power meter indication should cycle in four distinct steps of about 10-dB variation, at a rate of about one step per second.<br><br>***Note:*** With the main amplifier on MANUAL GAIN, the combiner phase control loop is open and the phase stepper should cycle through each of the four 90-degree phase quadrants. Each step should be indicated by a variation in the combined output signal of about 10 dB and at one point, when the phase relationship is 180 degrees out of phase, the meter indication should drop drastically. |

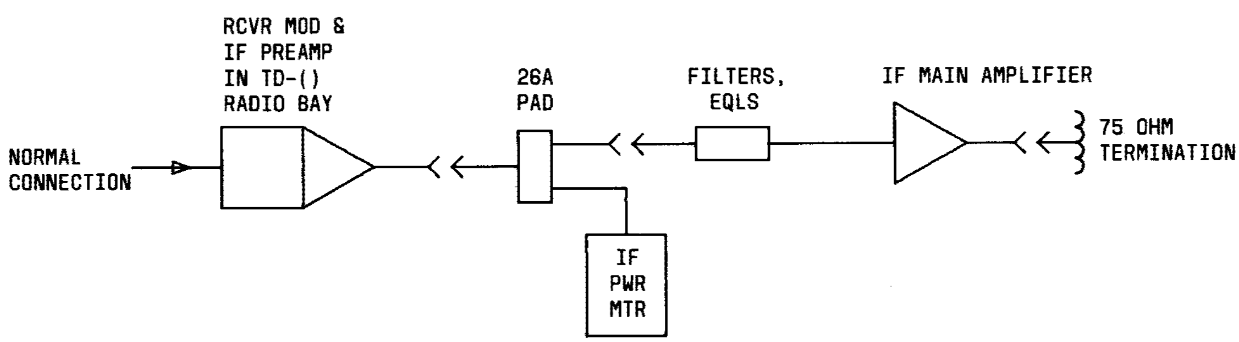


**Fig. 3—Test Arrangement for Checking Combiner Operation**

**CHART 2 (Contd)**

| STEP | PROCEDURE |
|---|---|
| 5 | Operate the AGC-MAN switch on the main amplifier to AGC.<br>***Requirement:*** The IF power meter indication should return to the same amplitude observed in Step 1 and should remain constant after the phase stepper has had time to step to the proper quadrant and the phase shifter has made the final adjustment of the diversity signal to cause in-phase addition of the regular and the diversity signals. |
| 6 | Operate the DIV ANT switch to OFF.<br>***Requirement:*** The ALM lamp shall light and the station audible alarm shall sound. |
| 7 | Operate the DIV ANT switch to ON.<br>***Requirement:*** The alarm lamp shall go out and the audible alarm shall silence. |
| 8 | Remove the split pad and power meter. Restore the radio bay connections to normal. |

## 5. TROUBLE CLEARING

**5.01** Replacement and installation procedures are provided in Charts 3 and 4.

**CHART 3**

**REPLACEMENT PROCEDURE**
**95A CONTROL UNIT**

***Caution: Internal components of the 713( ) IC may be damaged if the connector cable between the 95A control unit and the 713( ) IC is removed while the power is applied to the 95A unit. The power cord to the P1 connector on the 95A MUST be removed first and reconnected last.***

### CHART 3 (Contd)

| STEP | PROCEDURE |
|---|---|
| 1 | Remove the power cord connected to P1 connector on the 95A control unit. |
| 2 | Remove the connecting cable from J1 on the 95A unit to the 713( ) IC. |
| 3 | Locate the ends of the two locking bars at the bottom rear of the 95A unit. Slide the bars downward and remove the 95A unit by pulling the unit forward. |
| 4 | Mount the replacement 95A unit and, after making certain that all four mounting studs are properly seated, lock the unit in place by sliding the two locking bars up. |
| 5 | Connect the interconnecting cable between J1 and the 713( ) IC. |
| 6 | Connect the power cord to P1 on the 95A unit. |
| 7 | If necessary, operate the DIV ANT switch to ON. If the ALM lamp is lit, press the ALM RST button and note the ALM lamp goes out. If the lamp does not go out, remove the P1 power plug, verify that the interconnecting cable is properly seated then reconnect the P1 power plug. If the ALM lamp still does not go out, repeat this procedure using another 95A unit. |

### CHART 4

### REPLACEMENT PROCEDURE
### 713( ) INTEGRATED CIRCUIT

***Caution:* Internal components of the 713( ) IC may be damaged if the connector cable between the 95A control unit and the 713( ) IC is removed while the power is applied to the 95A unit. The power cord to the P1 connector on the 95A MUST be removed first and reconnected last.**

| STEP | PROCEDURE |
|---|---|
| 1 | Remove the 95A control unit as outlined in Chart 3. |
| 2 | The combiner unit is designed for use where the diversity antenna port is on either the left or the right of the main antenna port. Prior to removing the present unit, verify that the replacement unit is set up the same way. It may be necessary to move the 95A mounting screws from one side and to reorient the interconnecting cable so that it will be to the left side when mounted. |

CHART 4 (Contd)

| STEP | PROCEDURE |
|---|---|
| 3 | Remove the waveguide screws and dismount the present combiner.<br>***Note:*** Make certain that no dirt enters the waveguide system during the exchange of combiner units. |
| 4 | Install the replacement combiner and the waveguide screws. |
| 5 | Remount the 95A control unit as outlined in Chart 3. |
| 6 | Connect power cord P1 after other connections have been made. |