MOTOROLA

VISAR™
PORTABLE RADIO

Service with Theory/Maintenance

Computer Software Copyrights

68P81073C75-C

Motorola
8000 W. Sunrise Blvd.
Ft. Lauderdale, FL 33322-9947

MOTOROLA

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Foreword

Scope of Manual

This manual is intended for use by experienced technicians familiar with similar types of equipment. It contains all service information required for the equipment described and is current as of the printing date. Changes which occur after the printing date are incorporated by instruction manual revision. These revisions are added to the manuals as the engineering changes are incorporated into the equipment.

How to Use This Manual

This manual contains introductory material such as model charts, accessories, and specifications, as well as sections that deal with specific service aspects of the VISAR™ portable radio. Refer to the Table of Contents for a general overview of the manual.

Other Documentation

Table 1 lists other documentation for the VISAR Portable Radios.

Table 1. Other Documentations

Information	Location
Basic use of VISAR conventional radio	VISAR Operating Instructions (6881073C70)
Basic use of VISAR Privacy Plus® radio	VISAR Operating Instructions (6881076C95)
Programming	VISAR RSS Manual (6881073C55)

Technical Support

To obtain technical support, you may call Motorola's Product Customer Service. When you call, we ask that you have ready the model and serial numbers of the respective radio or its parts.

Customer Response Center
(Sales and Service Assistance)

1-800-247-2346 (Voice)
1-800-232-9272 (FAX)

Service Policy

You must obtain authorization from Product Customer Service before returning radios or components.

Ordering Replacement Parts

You can order additional components and some piece parts directly through your VISAR price pages. When ordering replacement parts, include the complete identification number for all chassis, kits, and components.

If you do not know a part number, include with your order the number of the chassis or kit which contains the part, and a detailed description of the desired component. If a Motorola part number is identified on a parts list, you should be able to order the part through Motorola Parts. If only a generic part is listed, the part is not normally available through Motorola. If no parts list is shown, generally, no user serviceable parts are available for the kit.

Motorola Radio Support Center

3761 South Central Avenue
Rockford, IL 61102-4294
1-815-489-1000

Motorola U. S. Federal Government Depot

7940 Penn Randall Place
Upper Marlboro, MD 20772-2627
1-800-969-6680
1-301-736-4300

Parts Information

7:00 A. M. to 7:00 P. M. (Central Standard Time)
Monday through Friday (Chicago, U. S. A.)
Domestic (U. S. A.): 1-800-422-4210, or 847-538-8023
1-800-826-1913, or 410-712-6200 (Federal Government)
TELEX: 280127
FAX: 1-847-538-8198
FAX: 1-410-712-4991 (Federal Government)
Domestic (U. S. A.) after hours or weekends:
1-800-925-4357
International: 1-847-538-8023

Motorola Parts

Accessories and Aftermarket Division
(United States and Canada)
Attention: Order Processing
1313 E. Algonquin Road
Schaumburg, IL 60196

Accessories and Aftermarket Division
Attention: International Order Processing
1313 E. Algonquin Road
Schaumburg, IL 60196

Customer Service/Order Entry

1-800-422-4210 (Voice)
1-847-538-8198 (FAX)

Parts Identification

1-847-538-0021 (Voice)
1-847-538-8194 (FAX)

List of Models

Table 2. VISAR Model Family of Conventional Systems Radios

Model Number	Description
H05KDD9AA4BN	16-Frequency, 2-Character Top Display, 5- to 1-Watt, 136 - 178MHz
H05KDH9AA7BN	16-Frequency, 2-Character Top Display, 5- to 1-Watt, 136 - 178MHz, 3 x 4 Keypad
H05RDD9AA4BN	16-Frequency, 2-Character Top Display, 4- to 1-Watt, 403 - 470MHz
H05RDH9AA7BN	16-Frequency, 2-Character Top Display, 4- to 1-Watt, 403 - 470MHz, 3 x 4 Keypad
H05SDD9AA4BN	16-Frequency, 2-Character Top Display, 4- to 1-Watt, 450 - 520MHz
H05SDH9AA7BN	16-Frequency, 2-Character Top Display, 4- to 1-Watt, 450 - 520MHz, 3 x 4 Keypad
H05UCD6AA4BN	16-Frequency, 2-Character Top Display, 3-Watt, 806 - 870MHz
H05UCH6AA7BN	16-Frequency, 2-Character Top Display, 3-Watt, 806 - 870MHz, 3 x 4 Keypad

Table 3. VISAR Model Family of Privacy Plus® Systems Radios

Model Number	Description
H05UCD6CB1BN	4 Systems, 4 Talkgroups, 2 Character Top Display, 3-Watt, 806-870MHz
H05UCH6DB7AN	4 Systems, 4 Talkgroups, 2 Character Top Display, 3-Watt, 806-870MHz, 3 x 4 Keypad

Table 4. VISAR Model Family of Privacy Plus® Type II System Radios

Model Number	Description
H05UCD6CF1BN	4 Systems, 4 Talkgroups, 2 Character Top Display, 3-Watt, 806-866MHz
H05WCD4CB1BN	4 Systems, 4 Talkgroups, 2 Character Top Display, 3-Watt, 896-902MHz

Model Numbering System

Typical Model Number:	H	0	5	K	D	D	9	A	A	4	A	N	S	P	0	1
Position:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

Position 1 - Type of Unit

H = Hand-Held Portable

Positions 2 & 3 - Model Series

Position 4 - Frequency Band

A = Less than 29.7MHz	P = 336 to 410MHz
B = 29.7 to 35.99MHz	Q = 403 to 437MHz
C = 36 to 41.99MHz	R = 438 to 482MHz
D = 42 to 50MHz	S = 470 to 520MHz
F = 66 to 80MHz	T = Product Specific
G = 74 to 90MHz	U = 806 to 870MHz
H = Product Specific	V = 825 to 870MHz
J = 136 to 162MHz	W = 896 to 941MHz
K = 146 to 178MHz	Y = 1.0 to 1.6GHz
L = 174 to 210MHz	Z = 1.5 to 2.0GHz
M = 190 to 235MHz	

Values given represent range only; they are not absolute.

Position 5 - Power Level

A = 0 to 0.7 Watts
B = 0.7 to 0.9 Watts
C = 1.0 to 3.9 Watts
D = 4.0 to 5.0 Watts
E = 5.1 to 6.0 Watts
F = 6.1 to 10 Watts

Position 6 - Physical Packages

A = RF Modem Operation
B = Receiver Only
C = Standard Control; No Display
D = Standard Control; With Display
E = Limited Keypad; No Display
F = Limited Keypad; With Display
G = Full Keypad; No Display
H = Full Keypad; With Display
J = Limited Controls; No Display
K = Limited Controls; Basic Display
L = Limited Controls; Limited Display
M = Rotary Controls; Standard Display
N = Enhanced Controls; Enhanced Display
P = Low Profile; No Display
Q = Low Profile; Basic Display
R = Low Profile; Basic Display, Full Keypad

Position 7 - Channel Spacing

1 = 5kHz	5 = 15kHz
2 = 6.25kHz	6 = 20/25kHz
3 = 10kHz	7 = 30kHz
4 = 12.5kHz	9 = Variable Programmable

Positions 13 - 16

"SP" Model Suffix

Position 12 - Unique Model Variations

C = Cenelec
N = Standard Package

Position 11 - Version

Version Letter (Alpha) - Major Change

Position 10 - Feature Level

1 = Basic	6 = Standard Plus
2 = Limited Package	7 = Expanded Package
3 = Limited Plus	8 = Expanded Plus
4 = Intermediate	9 = Full Feature/ Programmable
5 = Standard Package	

Position 9 - Primary System Type

A = Conventional
B = Privacy Plus®
C = Clear SMARTNET™
D = Advanced Conventional Stat-Alert™
E = Enhanced Privacy Plus®
F = Nauganet 888 Series
G = Japan Specialized Mobile Radio (JSMR)
H = Multi-Channel Access (MCA)
J = CoveragePLUS™
K = MPT1327* - Public
L = MPT1327* - Private
M = Radiocom
N = Tone Signalling
P = Binary Signalling
Q - Phonenet®
W = Programmable
X = Secure Conventional
Y = Secure SMARTNET™
** MPT = Ministry of Posts and Telecommunications*

Position 8 - Primary Operation

A = Conventinal/Simplex
B = Conventional/Duplex
C = Trunked Twin Type
D = Dual Mode Trunked
E = Dual Mode Trunked/Duplex
F = Trunked Type I
G = Trunked Type II
H = FDMA* Digital Dual Mode
J = TDMA** Digital Dual Mode
K = Single Sideband
L = Global Positioning Satellite Capable
M = Amplitude Companded Sideband (ACSB)
P = Programmable
** FDMA = Frequency Division Multiple Access*
*** TDMA = Time Division Multiple Access*

Glossary of Radio Communications and Electronics Terms

- **ALC**
  Automatic Level Control: a circuit in the transmit RF path that controls RF power amplifier output, provides leveling over frequency and voltage, and protects against high VSWR (voltage standing wave ration).
- **ASF IC**
  Audio Signalling Filter Integrated Circuit
- **DTMF**
  Dual-Tone Multifrequency
- **DPL**
  Digital Private-Line™
- **EEPROM**
  Electronically Erasable / Programmable Read-Only Memory: used by the radio to store its personality
- **Firmware**
  Software, or a software / hardware combination of computer programs and data, with a fixed logic configuration stored in a read-only memory. Information cannot be altered or reprogrammed.
- **FGU**
  Frequency Generation Unit
- **GaAs**
  Gallium Arsenide: a type of crystalline material used in some semiconductors.
- **ISW**
  Inbound Signalling Word: data transmitted on the control channel from a subscriber unit to the central control unit.
- **LCD**
  Liquid Crystal Display: a module used to display the radio's current operating channel or system and scan status.
- **LH DATA**
  Longhorn Data: a bidirectional 0-5V, RS-232 line that uses the microcontroller's integrated RS-232 asynchronous serial communications interface (SCI) peripheral.
- **LSH**
  Low-Speed Handshake: 150 baud digital data sent to the radio during trunked operation while receiving audio.
- **MDC**
  Motorola Digital Communication
- **MRTI**
  Motorola Radio-Telephone Interconnect: a system that provides a repeater connection to the Public Switched Telephone Network (PSTN). The MRTI allows the radio to access the telephone network when the proper access code is received.
- **MSK**
  Minimum-Shift Keying
- **OMPAC**
  Over-Molded Pad-Array Carrier: a Motorola custom package, distinguished by the presence of solder balls on the bottom pads.
- **OSW**
  Outbound Signalling Word: data transmitted on the control channel from the central controller to the subscriber unit.
- **PC Board**
  Printed Circuit Board
- **PL**
  Private-Line® tone squelch: a continuous subaudible tone that is transmitted along with the carrier.
- **PLL**
  Phase-Locked Loop: a circuit in which an oscillator is kept in phase with a reference, usually after passing through a frequency divider.
- **PTT**
  Push-To-Talk: the switch located on the left side of the radio which, when pressed, causes the radio to transmit.
- **RAM**
  Random Access Memory: the radio's RAM is loaded with a copy of the EEPROM data.
- **Registers**
  Short-term data-storage circuits within the microcontroller.
- **Repeater**
  Remote transmit / receive facility that retransmits received signals to improve communications coverage.
- **RESET**
  Reset line: an input to the microcontroller that restarts execution.
- **RF PA**
  Radio Frequency Power Amplifier

- **ROM**
  Read Only Memory
- **RSSI**
  Received Signal-Strength Indicator: a dc voltage proportional to the received RF signal strength.
- **RPT/TA**
  Repeater / Talk-Around
- **Softpot**
  Software Potentiometer: a computer-adjustable electronic attenuator
- **Software**
  Computer programs, procedures, rules, documentation, and data pertaining to the operation of a system
- **SPI (clock and data lines)**
  Serial Peripheral Interface: how the microcontroller communicates to modules and ICs through the CLOCK and DATA lines.
- **Squelch**
  Muting of audio circuits when received signal levels fall below a pre-determined value
- **Standby Mode**
  An operating mode whereby the radio is muted but still continues to receive data
- **System Central Controller**
  Main control unit of the trunked dispatch system; handles ISW and OSW messages to and from subscriber units (see ISW and OSW).
- **System Select**
  The act of selecting the desired operating system with the system-select switch (also, the name given to this switch).
- **TOT**
  Time-Out Timer: a timer that limits the length of a transmission.
- **µC**
  Microcontroller
- **µP**
  Microprocessor
- **VCO**
  Voltage-Controlled Oscillator: an oscillator whereby the frequency of oscillation can be varied by changing a control voltage.
- **VCOBIC**
  Voltage-Controlled Oscillator Buffer Integrated Circuit
- **VSWR**
  Voltage Standing Wave Ratio

Maintenance Specifications

(All specifications are per Electronic Industries Association (EIA) 316B, unless otherwise noted.)

Table 5. VHF Radios

General	Receiver	Transmitter
FCC Designation: AZ489FT3776	**Frequency Range:** *136–178MHz	**RF Power:** 136-174MHz variable 1Watt / 5 Watts 174-178MHz 1Watt / 4 Watts
Power Supply: Nickel-Metal-Hydride Battery	**Bandwidth:** 42MHz	**Frequency Range:** *136–178MHz
Battery Voltage: Nominal: 7.5 Volts Range: 6 to 9 Volts	**Quieting Sensitivity (20dBQ):** 0.5μV Max.	**Freq. Stability** (–30 to +60°C; 25°C ref.): ±.0005%
Battery Drain, Typical: Standby: 56mA Receive: 180mA Transmit: 1850mA (5W); 1200mA (2.5W); 900mA (1W)	**Usable Sensitivity** (12dB SINAD): 0.35μV Max.	**Emission (Conducted and Radiated):** –66dBw
Temperature Range: Operating: –30°C to +60°C Storage: –40°C to +85°C	**Intermodulation:** –70dB	**FM Hum and Noise** (Companion Receiver): –45dB Typical
Duty Cycle (5-5-90): 1 Watt / 5 Watts Medium Cap. Battery: 5.5 Hrs. / 4 Hrs. Ultra-High Cap. Battery: 11 Hrs. / 8 Hrs.	**Selectivity** (30kHz Adjacent Channel): –70dB	**Distortion:** 3% Typical
Dimensions (H x W x D)** Less Battery: 4.05" x 2.17" x 0.67" (10.28cm x 5.52cm x 1.70cm) With Medium Cap. Battery: 4.05" x 2.17" x 1.09" (10.28cm x 5.52cm x 2.76cm) With Ultra-High Cap. Battery: 4.05" x 2.17" x 1.49" (10.28cm x 5.52cm x 3.78cm)	**Spurious Rejection:** –70dB	**Modulation Limiting:** ±5kHz
Weight: (w/Helical Antenna) Less Battery: 5.9oz. (167gm) With Medium Cap. Battery: 11.5oz. (326gm) With Ultra–High Cap. Battery: 14.8oz. (420gm)	**Freq. Stability** (–30 to +60°C; 25°C reference): ± 0.0005%	**Recommended Battery:** Medium Capacity: NTN7396 Ultra–High Capacity: NTN7394
	Rated Audio: 500mW	
	Distortion (At Rated Audio): 3% Typical	
	Channel Spacing: 30kHz	

Specifications subject to change without notice.

* Frequencies in the 174-178MHz range are not permitted in the USA.

** Measured at base of radio.

Table 6. UHF Radios

General	Receiver	Transmitter
FCC Designation: AZ489FT4792	**Frequency Range:** 403-470MHz *450-520MHz	**RF Power:** 403-470MHz variable 1 Watt / 4 Watts 450-512MHz 1Watt / 4 Watts 512-520MHz 1Watt / 3 Watts
Power Supply: Nickel-Metal-Hydride Battery	**Bandwidth:** 70MHz	**Frequency Range:** 403-470MHz *450-520MHz
Battery Voltage: Nominal: 7.5 Volts Range: 6 to 9 Volts	**Quieting Sensitivity (20dBQ):** 0.5µV Max.	**Freq. Stability** (–30 to +60°C; 25°C ref.): ±.0005%
Battery Drain, Typical: Standby: 60mA Receive: 180mA Transmit: 1800mA (4W); 1300mA (2W); 1000mA (1W)	**Usable Sensitivity** (12dB SINAD): 0.35µV Max.	**Emission (Conducted and Radiated):** –66dBw
Temperature Range: Operating: –30°C to +60°C Storage: –40°C to +85°C	**Intermodulation:** –70dB	**FM Hum and Noise** (Companion Receiver): –45dB Typical
Duty Cycle (5-5-90): 1 Watt / 4 Watts Medium Cap. Battery: 5.5 Hrs. / 4 Hrs. Ultra-High Cap. Battery: 11 Hrs. / 8 Hrs.	**Selectivity** (30kHz Adjacent Channel): –70dB	**Distortion:** 3% Typical
Dimensions (H x W x D)** Less Battery: 4.05" x 2.17" x 0.67" (10.28cm x 5.52cm x 1.70cm) With Medium Cap. Battery: 4.05" x 2.17" x 1.09" (10.28cm x 5.52cm x 2.76cm) With Ultra-High Cap. Battery: 4.05" x 2.17" x 1.49" (10.28cm x 5.52cm x 3.78cm)	**Spurious Rejection:** 450-512MHz –70dB 512-520MHz –65dB	**Modulation Limiting:** ±5kHz
Weight: (w/Helical Antenna) Less Battery: 5.9oz. (167gm) With Medium Cap. Battery: 11.5oz. (326gm) With Ultra–High Cap. Battery: 14.8oz. (420gm)	**Freq. Stability** (–30 to +60°C; 25°C reference): ± 0.0005%	**Recommended Battery:** Medium Capacity: NTN7396 Ultra–High Capacity: NTN7394
	Rated Audio: 500mW	
	Distortion (At Rated Audio): 3% Typical	
	Channel Spacing: 25kHz	

Specifications subject to change without notice.

* Frequencies in the 512-520MHz range are not permitted in the USA.

** Measured at base of radio.

Table 7. 800MHz Radios

General		Receiver		Transmitter	
FCC Designation:	AZ489FT5760	**Frequency Range:**	851–866MHz	**RF Power:**	3 Watts
Power Supply:	Nickel-Metal-Hydride Battery	**Bandwidth:**	19MHz	**Frequency Range:**	806–821MHz 851–866MHz
Battery Voltage: Nominal: Range:	 7.5 Volts 6 to 9 Volts	**Quieting Sensitivity (20dBQ):**	0.5µV Max.	**Freq. Stability** (–30 to +60°C; 25°C ref.):	 ±.00025%
Battery Drain, Typical: Standby: Receive: Transmit:	 65mA 190mA 1900mA	**Usable Sensitivity** (12dB SINAD):	 0.35µV Max.	**Emission (Conducted and Radiated):**	 –46dBw
Temperature Range: Operating: Storage:	 –30°C to +60°C –40°C to +85°C	**Intermodulation:**	–70dB	**FM Hum and Noise** (Companion Receiver):	 –40dB
Duty Cycle (5-5-90): Medium Cap. Battery: Ultra-High Cap. Battery:	 4 Hours 8 Hours	**Selectivity** (30kHz Adjacent Channel):	 –70dB	**Distortion:**	3% Typical
Dimensions (H x W x D)** Less Battery: With Medium Cap. Battery: With Ultra-High Cap. Battery:	 4.05" x 2.17" x 0.67" (10.28cm x 5.52cm x 1.70cm) 4.05" x 2.17" x 1.09" (10.28cm x 5.52cm x 2.76cm) 4.05" x 2.17" x 1.49" (10.28cm x 5.52cm x 3.78cm)	**Spurious Rejection:**	–70dB	**Modulation Limiting:**	±5kHz
Weight: (w/Helical Antenna) Less Battery: With Medium Cap. Battery: With Ultra–High Cap. Battery:	 5.9oz. (167gm) 11.5oz. (326gm) 14.8oz. (420gm)	**Freq. Stability** (–30 to +60°C; 25°C reference):	 ±.00025%	**Recommended Battery:** Medium Capacity: Ultra–High Capacity:	 NTN7396 NTN7394
		Rated Audio:	500mW		
		Distortion (At Rated Audio):	3% Typical		
		Channel Spacing:	25kHz		

Specifications subject to change without notice.

** Measured at base of radio.

Table 8. 900MHz Radios

General		Receiver		Transmitter	
FCC Designation:	AZ489FT5768	**Frequency Range:**	935-941MHz	**RF Power:**	2.9 Watts
Power Supply:	Nickel-Metal-Hydride Battery	**Bandwidth:**	6MHz	**Frequency Range:**	896-902MHz 935-941MHz
Battery Voltage: Nominal: Range:	 7.5 Volts 6 to 9 Volts	**Quieting Sensitivity (20dBQ):**	0.5µV Max.	**Freq. Stability** (–30 to +60°C; 25°C ref.):	 ±.00015%
Battery Drain, Typical: Standby: Receive: Transmit:	 70mA 195mA 1900mA	**Usable Sensitivity** (12dB SINAD):	 0.35µV Max.	**Emission (Conducted and Radiated):**	–46dBw
Temperature Range: Operating: Storage:	 –30°C to +60°C –40°C to +85°C	**Intermodulation:**	–60dB	**FM Hum and Noise** (Companion Receiver HearClear):	–45dB Typical
Duty Cycle (5-5-90): Medium Cap. Battery: Ultra-High Cap. Battery:	 4 Hours 8 Hours	**Selectivity** (30kHz Adjacent Channel):	 –60dB	**Distortion:**	3% Typical
Dimensions (H x W x D)** Less Battery: With Medium Cap. Battery: With Ultra-High Cap. Battery:	 4.05" x 2.17" x 0.67" (10.28cm x 5.52cm x 1.70cm) 4.05" x 2.17" x 1.09" (10.28cm x 5.52cm x 2.76cm) 4.05" x 2.17" x 1.49" (10.28cm x 5.52cm x 3.78cm)	**Spurious Rejection:**	–60dB	**Modulation Limiting:**	±2.5kHz
Weight: (w/Helical Antenna) Less Battery: With Medium Cap. Battery: With Ultra–High Cap. Battery:	 5.9oz. (167gm) 11.5oz. (326gm) 14.8oz. (420gm)	**Freq. Stability** (–30 to +60°C; 25°C reference):	 ± 0.00015%	**Recommended Battery:** Medium Capacity: Ultra–High Capacity:	 NTN7396 NTN7394
		Rated Audio:	500mW		
		Distortion (At Rated Audio):	3% Typical		
		Channel Spacing:	12.5kHz		

Specifications subject to change without notice.

** Measured at base of radio.

Model Chart

VISAR™
Portable Radios

Models	Description
H05KDD9AA4DN	16-Freq., 2-Char. Top Display, 5- to 1- Watt, No Keypad, 136-178MHz
H05KDH9AA7DN	16-Freq., 2-Character Top Display, 5- to 1- Watt, Keypad, 136-178MHz
H05RDD9AA4DN	16-Freq., 2-Char.Top Display, 4- to 1- Watt, No Keypad, 403-470MHz
H05RDH9AA7DN	16-Freq., 2-Character Top Display, 4- to 1- Watt, Keypad, 403-470MHz
H05SDD9AA4DN	16-Freq., 2-Char. Top Display, 4- to 1- Watt, No Keypad, 450-520MHz
H05SDH9AA7DN	16-Freq., 2-Character Top Display, 4- to 1- Watt, Keypad, 450-520MHz
H05UCD6AA4DN	16-Freq., 2-Character Top Display, 3- Watt, No Keypad, 870MHz
H05UCH6AA7DN	16-Freq., 2-Character Top Display, 3- Watt, Keypad, 870MHz

H05KDD9AA4DN	H05KDH9AA7DN	H05RDD9AA4DN	H05RDH9AA7DN	H05SDD9AA4DN	H05SDH9AA7DN	H05UCD6AA4DN	H05UCH6AA7DN	Kit	Description
								RF Kits	**Description**
X	X							NUD7093B	VHF (136-178Mz) Transceiver Board
		X	X					NUE7269B	UHF (403-470MHz) Transceiver Board
				X	X			NUE7270B	UHF (450-520MHz) Transceiver Board
						X	X	NUF6505B	800MHz Transceiver Board
								Hardware Kit	**Description**
X	X	X	X	X	X	X	X	NTN8140A	Hardware Model Assembly
								Front Cover Kits	**Description**
	X		X		X			NHN6722A	3 x 4 Keypad Kit
X		X		X				NHN6723A	Non-Keypad Kit
							X	NHN6730A	3 x 4 Keypad Kit
						X		NHN6729A	Non-Keypad Kit
								Controller Kits	**Description**
X	X	X	X	X	X	X	X	NCN6143C	Conventional Systems Radios

x = included

Section 1
Introduction

About This Manual

This manual includes

- specifications,
- fundamental disassembly/reassembly procedures,
- schematic diagrams, component location diagrams,
- flex circuit diagrams,
- several parts lists,
- theory of operation,
- and troubleshooting sections to cover the VISAR radios.

Hereafter, the text will refer collectively to the VISAR radios as "this family of radios."

For operation of the radio, refer to the applicable manual available separately. To help you with your selection, a list is provided in Table 1 on page vii.

Throughout this publication, you will notice the use of warnings, cautions, and notes. These notations are used to emphasize that safety hazards exist, and care must be taken and observed.

WARNING

An operational procedure, practice, or condition, etc., which may result in injury or death if not carefully observed.

CAUTION

An operational procedure, practice, or condition, etc., which may result in damage to the equipment if not carefully observed.

NOTE

An operational procedure, practice, or condition, etc., which requires emphasis.

Safe and Efficient Operation of Motorola Two-way Radios

Scope

This section provides information and instructions for the safe and efficient operation of Motorola portable andmmobile two-way radios.

The information provided in this document supersedes the general safety information contained in user guides published prior to 1st January 1998.

For information regarding radio use in a hazardous atmosphere, please refer to the Factory Mutual (FM) Approval Manual Supplement or Instruction Card, which is included with radio models that offer this capability.

Exposure to Radio Frequency Energy

National and International Standards and Guidelines

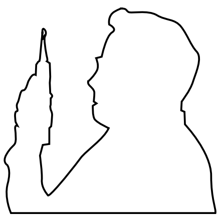
Your Motorola two-way Radio, which generates and radiates radio frequency (RF) electromagnetic energy (EME) is designed to comply with the following national and international standards and guidelines regarding exposure of human beings to radio frequency electromagnetic energy:

- Federal Communications Commission Report and Order No. FCC 96-326 (August 1996)
- American National Standards Institute (C95-1-1992)
- National Council on Radiation Protection and Measurements (NCRP - 1986)
- International Commission on Non-Ionizing Radiation Protection (ICNRP - 1986)
- European Committee for Electrotechnical Standardization (CENELEC)
  - Env. 50166 - 1 1995E - Human Exposure to Electromagnetic Fields Low Frequency (0 Hz to 10kHz)
  - Env. 50166 - 2 1995E - Human Exposure to Electromagnetic Fields High Frequency (10kHz to 300Ghz)
  - Proceedings of SC211/8 1996 - Safety Considerations for Human Exposure to E.M.Fs from Mobile Telecommunications Equipment (M.T.E.) in the Frequency Range 30MHz - 6GHz (E.M.F - Electromagnetic Fields)

To assure optimal radio performance and that human exposure to radio frequency electromagnetic energy is within the guidelines set forth in the above standards, always adhere to the following procedures:

Portable Radio Operation and EME Exposure

- When transmitting with a portable radio, hold the radio in a vertical position with its microphone 1 to 2 inches (2.5 to 5.0 centimeters) away from your mouth. Keep antenna at least 1 inch (2.5 centimeters) from your head and body.



- If you wear a portable two-way radio on your body, ensure that the antenna is at least 1 inch (2.5 centimeters) from your body when transmitting.

Electromagnetic Interference/ Compatibility-Usage Guidelines

NOTE

Nearly every electronic device is susceptible to electromagnetic interference (EMI) if inadequately shielded, designed, or otherwise configured for electromagnetic compatibility.

RF-Sensitive Environments

To avoid electromagnetic interference and / or compatibility conflicts, turn off your radio in any facility where posted notices instruct you to do so. Hospitals or health care facilities may be using equipment that is sensitive to external RF energy.

Air Travel

When instructed to do so, turn off your radio when on board an aircraft. Any use of a radio must be in accordance with airline regulations or crew instructions.

Operational Warnings

For Vehicles with an Air Bag

WARNING

Do not place a portable radio in the area over an air bag or in the air bag deployment area. Air bags inflate with great force. If a portable radio is placed in the air bag deployment area and the air bag inflates, the radio may be propelled with great force and cause serious injury to occupants of the vehicle.

Potentially Explosive Atmospheres

WARNING

Turn off your two-way radio when you are in any area with a potentially explosive atmosphere, unless it is a radio type especially qualified for use in such areas (for example, Factory Mutual Approved). Sparks in a potentially explosive atmosphere can cause an explosion or fire resulting in bodily injury or even death.

Batteries

WARNING

Do not replace or charge batteries in a potentially explosive atmosphere. Contact sparking may occur while installing or removing batteries and cause an explosion.

Blasting Caps and Areas

WARNING

To avoid possible interference with blasting operations, turn off your radio when you are near electrical blasting caps, in a blasting area, or in areas posted: *Turn off two-way radio*. Obey all signs and instructions.

NOTE

The areas with potentially explosive atmospheres referred to above include fueling areas such as:

- below decks on boats;
- fuel or chemical transfer or storage facilities;
- areas where the air contains chemicals or particles, such as grain, dust or metal powders;
- and any other area where you would normally be advised to turn off your vehicle engine.

Areas with potentially explosive atmospheres are often but not always posted.

Operational Cautions

Damaged Antennas

CAUTION

Do not use any portable two-way radio that has a damaged antenna. If a damaged antenna comes into contact with your skin, a minor burn can result.

Batteries

CAUTION

All batteries can cause property damage and/or bodily injury such as burns if a conductive material such as jewelry, keys, or beaded chains touch exposed terminals. The conductive material may complete an electrical circuit (short circuit) and become quite hot.

Exercise care in handling any charged battery, particularly when placing it inside a pocket, purse, or other container with metal objects.

Mobile Radio Operation and EME Exposure

To assure optimal radio performance and that human exposure to radio frequency electromagnetic energy is within the guidelines referenced earlier in this document, transmit *only* when people inside and outside the vehicle are at least the minimum distance away from a properly installed, externally-mounted antenna.

Table 1-1. Rated Power and Distance

Rated Power of Vehicle-installed Mobile Two-way Radio	Minimum Distance from Transmitting Antenna
7 to 15 Watts	1 Foot (30.5 Centimeters)
16 to 50 Watts	2 Feet (61 Centimeters)
More than 50 Watts	3 Feet (91.5 Centimeters)

Mobile Antenna Installation

Install the vehicle antenna *external* to the vehicle and in accordance with:

a. The requirements of the antenna manufacturer/supplier

b. Instructions in the Radio Installation Manual

Control Station Operation

When radio equipment is used to operate as a control station, it is important that the antenna be installed outside the building and away from places where people may be in close proximity.

NOTE

Refer to Table 1-1 for rated power and minimum distance values for transmitting antennas.

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Section 2
Operating Instructions
(Quick-Reference Description)

Introduction

Purpose

This section provides a basic explanation of the operation of the VISAR portable radio, including some of its main features. Most of the information in this section is also available in the quick reference cards which accompany the VISAR operating instructions manuals. A detailed description of the operation, features, and safety instructions for the VISAR radio will be found in the following manuals:

Model	Manual Number
Conventional (VHF, UHF, 800MHz)	68P81073C70
Privacy Plus® (800 and 900MHz)	68P81076C95

To order these manuals, please call:

Motorola
Accessories and Aftermarket Division
1-800-422-4210

Conventional (VHF, UHF, 800MHz) and PrivacyPlus (800 and 900MHz) Radios (Refer to Figure 2-1)

Receiving

Turn the radio on, scroll to the desired channel using the selector buttons on the front of the radio, and monitor for activity. Press the middle side button to unsquelch the radio if you don't hear a transmission.

Transmitting

Turn the radio on and select the desired channel using the selector buttons. Momentarily press the middle side button to be sure the channel is clear. When clear, press the PTT switch (the bottom side button), the red LED will light, and speak into the microphone area. Release the PTT switch to receive.

Conventional Radio Features

Monitoring

Turn the radio on using the on / off volume control knob. To monitor, momentarily press the middle side button and adjust the on / off volume control for comfortable listening.

Channel Scan™

Turn the radio on. With auto scan, scroll using the selector buttons to the preprogrammed scan channel. With preprogrammed scan, activate scan using the top side button.

Stat-Alert ™ Signalling Features

- PTT-ID is a per-channel feature. An ID code is sent upon pressing the PTT switch. This allows the dispatcher to identify the transmitting radio.
- Emergency alarm is a per-radio feature. An emergency code is transmitted when the preprogrammed top side button is pressed. To cancel the alarm, do the following:

  press the PTT switch;

  or, hold down the top side button;

  or, turn off the radio.
- Call Alert™ is a per-radio feature. When a call alert (page) is received, four beeps sound and the LED flashes green until the PTT switch is pressed; or, until the middle side button is pressed and released.
- Voice Selective Call radios receive a voice message: a one-time, two-beep tone sounds and the LED lights green. The radio returns to normal operation at the end of the voice message.
- Repeater access-equipped radios transmit a code in one of two ways:

1. automatically, prior to data and voicetransmission, oror, turn off the radio.
2. manually, by pressing the top or middle side button.

Quik-Call II™ Decode Signalling

Quik-Call II is a per-radio feature enabled on a per-channel basis and offered as individual call, group call, and dual call. It allows the dispatcher to voice-page a radio, or radios.

Activate by turning on the radio and scrolling (using the selector buttons) to the channel preprogrammed for Quik-Call. The green LED flashes and an alert tone sounds when a page is received. The radio resets automatically to the Quik-Call mode (if programmed for auto reset), or when the middle side button is pressed.

Touch-Code™ (DTMF)

A VISAR radio equipped with a keypad and DTMF programming will be able to place and receive phone calls.

- To call with auto access, press the top side button, listen for the dial tone, and dial using the keypad. Press the top side button to hang up.
- To call with manual dial, access the phone mode by pressing the top side button. Enter the access code using the keypad. Proceed as with auto access.

Smart PTT

With this per-channel feature enabled, two actions are not permitted:

1. The radio will not transmit on a busy channel;
2. The radio will not monitor channels programmed with smart PTT.

Pressing the PTT switch on a busy (smart PTT) channel causes a continuous alert tone to sound until the PTT switch is released. Transmission is prevented.

PAC•RT®

Radios with PAC•RT communicate through a vehicular repeater to a base station.

Activate by turning on the radio and scrolling (using the selector buttons) to a channel with PAC•RT. All messages are communicated portable-to-base when PAC•RT is selected. If the PAC•RT channel is not selected, the radio transmits and receives portable-to-portable.

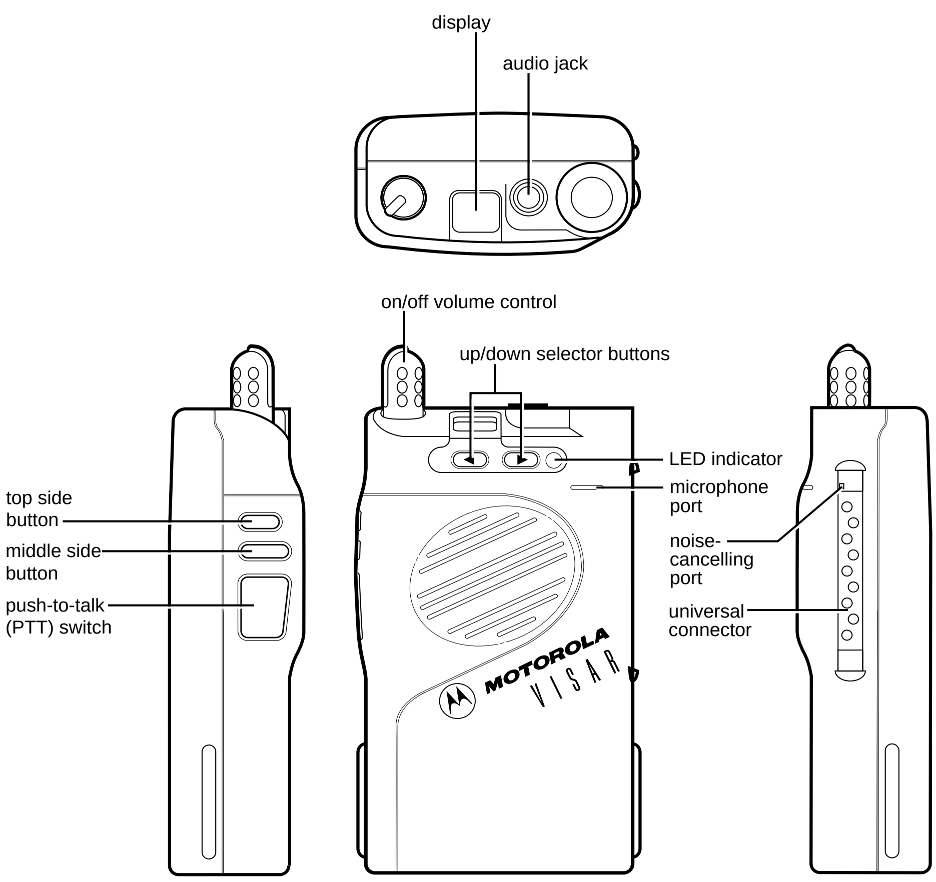

Figure 2-1. VISAR Controls, Switches, Indicators, and Connectors

Section 3
Recommended Test Equipment, Service Aids, and Tools Lists

Recommended Test Equipment

The list of equipment contained in Table 3-1 includes all of the standard test equipment required for servicing two-way portable radios, as well as several unique items designed specifically for servicing this family of radios. Battery-operated test equipment is recommended when available. The "Characteristics" column is included so that equivalent equipment may be substituted; however, when no information is provided in this column, the specific Motorola model listed is either a unique item or no substitution is recommended.

Table 3-1. Recommended Test Equipment

Motorola Model Number	Description	Characteristics	Application
R2000 Series R2600 Series	System Analyzer	This monitor will substitute for items with an asterisk (*)	Frequency / deviation meter and signal generator for wide-range troubleshooting and alignment
*R1049A	Digital Multimeter		Digital voltmeter recommended for ac / dc voltage and current measurements
*R1150C	Code Synthesizer		Injection of audio and digital signalling codes
*S1053D *SKN6008A *SKN6001A	AC Voltmeter Power Cable for Meter Test Leads for Meter	1mV to 300V, 10-Megohminput impedance	Audio voltage measurements
R1094A	Dual-Trace Oscilloscope	20MHz bandwidth 5mV to 5V / division	Waveform measurements
*S1350C *ST1213B (VHF) *ST1223B (UHF)	Watt Meter Plug-in Element RF Dummy Load	50-ohm, ±5% accuracy 10 Watts, maximum 0-1000MHz, 300W	Transmitter power output measurements
R1065	Load Resistor	10-watt Broadband	For use with Wattmeter
S1339A	RF Millivolt Meter	100µV to 3V RF 10kHz to 1.2GHz	RF level measurements
*R1013A	SINAD Meter		Receiver sensitivity measurements
S1347D or S1348D (programmable)	DC Power Supply	0-20Vdc, 0-5 Amps current limited	Bench supply for 7.5Vdc

*Any of the R2000 series system analyzers will substitute for items with an asterisk (*).

Service Aids and Recommended Tools

Refer to "SERVICE AIDS" and "RECOMMENDED TEST TOOLS" for a listing and description of the service aids and tools designed specifically for servicing this family of radios, as well as the more common tools required to disassemble and properly maintain the radio. These kits and / or parts are available from the Motorola Communications Parts office listed in the "Replacement Parts Ordering" section of this manual.

Some VHS format video cassettes and supplemental literature describing the removal and replacement of leadless components using the R-1070A surface-mounted IC removal station might be available for this radio:

- 0180386A62 Heated Tweezers,
- 0180356B79 Desoldering Station, and
- 0180371B30 Soldering Station.

Video service education tapes are recommended for technicians who intend to service this and other Motorola radios using leadless components. Video tapes, if available, are in VHS standard half-inch format.

You may inquire about the availability of video tapes and other service aids by writing to:

Motorola C&E, Inc.
Worldwide Technical Education
1300 N. Plum Grove Road
Schaumburg, Illinois 60195

Field Programming

This family of radios can be aligned and programmed in the field. This requires specific equipment and special instructions. Refer to the applicable “Radio Service Software User's Manual” for complete field programming information.

The following table lists service aids recommended for working on this family of radios. While all of these items are available from Motorola, most are standard shop equipment items. Any equivalent item capable of the same performance may be substituted for the item listed.

Table 3-2. Service Aids

Motorola Part Number	Description	Application
RKN-4042A	RIB / Radio / Test Set Cable	Connects radio to RTX-4005B Test Box and RIB.
RLN-4327A RLN-4326A, or both	Battery Eliminator	Interconnects radio to power supply
RLN1018A and 0180301 E44	Housing Eliminator Test Fixture	Provides for troubleshooting of the radio when the housing is removed. Use 0180301E44 adaptor if the RLN1018A is RLN1018A and 0180301 E44 Housing Eliminator already available.
5880348B33	SMA to BNC Adaptor	Adapts radio’s antenna port to BNC cabling of test equipment.
RTX-4005B	Portable Test Set	Enables connection to the universal connector.
RTX-4005A and RPX-4665A	Field Modification Kit	Allows switching for radio testing.
RLN-4008B	Radio Interface Box	Enables communications between the radio and the computer's serial communications adapter.
0180357A57 0180358A56	Wall-Mounted Power Supply Used to supply power to the RIB (120 VAC).	Used to supply power to the RIB (120 VAC).
3080369B71 or 3080369B72	Computer Interface Cable	Use B72 for the IBM PC AT. All other IBM models use B71. Connects the computer's serial communications adapter to the RIB
RKN-4043A	Cloning Cable	Allows a radio to be duplicated from a master radio by transferring programmed data from one radio to another.
RVN-4098C RVN-4123A*	Radio Service Software	Software on 3-1/2 in. and 5-1/4 in. floppy disks.
TT907A National Service Technical Guide	Repairing Leadless Component Assemblies	How to successfully remove and replace surface mount devices.

* For Privacy Plus

The following table lists the tools recommended for working on this family of radios; these tools are also available from Motorola. Note that the R-1070A workstation requires the use of a specific "heat-focus head" for each of the components on which this item is used. Each of these heat-focus heads must be ordered separately. The individual heat-focus heads (and the components on which they are used) are listed at the end of the table.

Table 3-3. Recommended Test Tools

Motorola Part Number	Description	Application
6680387A59	Extractor, 2-contact	Removal of discrete surface-mounted devices
6680387A64	Heat controller with safety stand, or	
6680387A65	Safety stand only	
0180382A31	Portable desoldering unit	
6680375A74	0.025 replacement tip, 5 / pk	For 0180382A31 portable desoldering unit
0180386A81	Miniature digital readout soldering station (included. 1 / 64" micropoint tip)	
0180386A78	Illuminated magnifying glass with lens attachment	
0180386A82	Anti-static grounding kit	Used during all radio assembly and disassembly procedures
6684253C72	Straight prober	
6680384A98	Brush	
1010041A86	Solder (RMA type), 63 / 37, 0.020" diameter-1 lb. spool	
1080370B43	RMA liquid flux	
R-1070A	Shields and surface-mounted component - IC removal / rework station (order all heat-focus heads separately)	Removal and assembly of surface-mounted integrated circuits and shields
or, R-1319A	Shields and surface-mounted component - IC removal / rework station SMD10000 M.A.P.E.	Removal and assembly of surface-mounted integrated circuits and shields

Table 3-4. Heat-focus Heads

Heat-focus Heads	Inside Dimensions of Heads	Application	Maximum Prescribed Heat Setting
6680334B49	0.410" x 0.410"	U601, U702	450° C
6680334B50	0.430" x 0.430"	U4, U5	
6680334B51	0.492" x 0.492"	U3, U707	
6680334B52	0.572" x 0.572"	U701, U705	
6680334B53	0.670" x 0.790"	* metal shields B, C, E, and F	550° C
6680370B51	0.475" x 0.475"	U204	450° C
6680370B57	0.245" x 0.245"	U2, U201	400° C
6680370B58	0.340" x 0.340"	U101, U102	
6680371B15	0.460" x 0.560"	* metal shields A, D, G, H, and I	380° C
6680371B74	0.470" x 0.570"	U203	450° C

* Refer to the SHIELDS LOCATION DETAIL and Shields Parts List in the rear of this manual to match the shield with the proper heat-focus head.

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Section 4
Transceiver Performance Testing

General

The VISAR radios have been prepared to meet published specifications through their manufacturing process, with the use of laboratory-quality test equipment of highest accuracy. The recommended field service equipment approaches the accuracy of the manufacturing equipment with a few exceptions. Accuracy of the equipment must be maintained in compliance with the manufacturer's recommended calibration schedule.

Setup

Supply voltage can be connected from the battery eliminator. The equipment required for alignment procedures is connected as shown in the Radio Alignment Test Setup diagram.

Initial equipment control settings should be as indicated in the following table, and should hold for all alignment procedures except as noted in Table 4-1.

Table 4-1. Initial Equipment Control Settings

Service Monitor	Test Set	Power Supply
Monitor Mode: Pwr Mon	Spkr set: A	Voltage: 7.5Vdc
RF Attn: –70	Spkr / load: Speaker	DC on / standby: Standby
AM, CW, FM: FM	PTT: OFF (center)	Volt Range: 10
Oscilloscope Source: Mod Oscilloscope Horiz: 10mSec / Div Oscilloscope Vert: 2.5kHz / Div Oscilloscope Trig: Auto Monitor Image: Hi Monitor BW: Near Monitor Squelch: mid CW Monitor Val: 1 / 4 CW		Current: 2.5

Test Mode

RF Test Mode

When the VISAR radio is operating in its normal environment, the radio's microcontroller controls the RF channel selection, transmitter key-up, and receiver muting. However, when the unit is on the bench for testing, alignment, or repair, it is removed from its normal environment. It cannot receive commands from its system and, therefore, the internal microcontroller will not key the transmitter nor inmate the receiver. This prevents the use of normal tune-up procedures. To solve this problem a special routine, called TEST MODE or “air test,” has been incorporated in the radio.

To enter test mode:

- Turn the radio on.
- Within ten seconds after the self test is complete, press the monitor button (side button 2, SB2) five times in succession.
- After “RF TEST” appears in the display, the radio is on the radio test frequency 1, carrier squelch mode.
- Each additional press of SB2 will advance to the next test channel (refer to Table 4-3). A corresponding set of tones will indicate the channel.
- Pressing SB1 will scroll through and access test environments as shown in Table 4-2.

NOTE
Transmit into a load when keying a radio under test

Table 4-2. Test Environments

Number of Beeps	Description	Function
1	Carrier Squelch	RX:if carrier detected TX: mic audio
2	HearClear™	RX: audio routing (900MHz only)
3	Tone Private-Line	RX:unsquelch if carrier and tone (192.8Hz) detected TX: mic audio + tone (192.8Hz)
4	Digital Private-Line	RX:unsquelch if carrier and digital code (131) detected TX: mic audio + digital code (131) detected
5	Trunking Low Speed	RX: unsquelch if carrier detected TX: mic audio + connect tone (105.8Hz) @ correct deviation
6	Trunking High Speed	RX:unsquelch if valid outbound signalling word (OSW) detected TX: 1500Hz tone
7	Dual-Tone multiple frequency	RX:unsquelch if carrier detected TX: selected DTMF tone pair
8	MDC1200	RX:unsquelch if carrier detected without DOS (1800Hz); squelch if carrier detected with DOS (1800Hz) TX: 1500Hz tone
11	Unsquelch***	RX:constant unsquelch TX: mic audio

***not available on all radios

Table 4-3. Test Frequencies

Number of Beeps	Test Channel	VHF	UHF Band 1	UHF Band 2	800MHz	900MHz
1	TX #1 RX #1	136.025 136.075	403.100 403.150	450.025 450.075	806.0125 851.0625	896.0125 935.0625
2	TX #2 RX #2	142.125 142.175	424.850 424.900	465.225 465.275	815.0125 860.0625	899.0125 938.0625
3	TX #3 RX #3	154.225 154.275	438.050 438.100	475.225 475.275	824.9875 869.9375	901.9875 940.9375
4	TX #4 RX #4	160.125 160.175	444.050 444.100	484.975 485.025	851.0125 851.0625	935.0125 935.0625
5	TX #5 RX #5	168.075 168.125	456.350 456.400	500.275 500.325	860.0125 860.0625	938.0125 938.0625
6	TX #6 RX #6	173.975 173.925	463.700 463.650	511.975 511.925	869.9875 869.9375	940.9875 940.9375
7	TX #7 RX #7	177.975 177.925	469.650 469.700	519.975 519.925	None None	None None

Table 4-4. Receiver Performance Checks

Test Name	Communications Analyzer	Radio	Test Set	Comments
Reference Frequency	Mode: PWR MON 4th channel test frequency* Monitor: Frequency error Input at RF In / Out	TEST MODE, Test Channel 4 carrier squelch output at antenna	PTT to continuous (during the performance check)	Frequency error to be ±150Hz
Related Audio	Mode: GEN Output level: 1.0mV rf 4th channel test frequency* Mod: 1kHz tone at 3kHz deviation Monitor: DVM: AC Volts	TEST MODE, Test Channel 4 carrier squelch	PTT to OFF (center), meter selector to Audio PA	Set volume control to 3.74Vrms
Distortion	As above, except to distortion	As above	As above	Distortion < 3.0%
Sensitivity (SINAD)	As above, except SINAD, lower the rf level for 12dB SINAD.	As above	PTT to OFF (center)	RF input to be < 0.35μV
Noise Squelch Threshold (only radios with conventional system need to be tested)	RF level set to 1mV RF	As above	PTT to OFF (center), meter selection to Audio PA, spkr / load to speaker	Set volume control to 3.74Vrms
	As above, except change frequency to a conventional system. Raise rf level from zero until radio unsquelches.	out of TEST MODE; select a conventional system	As above	Unsquelch to occur at < 0.25μV. Preferred SINAD = 8-10dB

* See Table 4-3

Table 4-5. Transmitter Performance Checks

TEST NAME	COMMUNICATIONS ANALYZER	RADIO	TEST SET	COMMENTS
Reference Frequency	Mode: PWR MON 4th channel test frequency* Monitor: Frequency error Input at RF In / Out.	TEST MODE, Test Channel 4 carrier squelch	PTT to continuous (during the performance check).	Frequency error to be < 150Hz
Power rf	As above.	As above	As above	Refer to Maintenance Specifications page in front of manual.
Voice Modulation	Mode: PWR MON 4th channel test frequency* attent to –70, input to rf In / Out, Monitor: DVM, AC Volts Set 1kHz Mod Out level for 0.025Vrms at test set, 80mVrms at AC / DC test set jack	As above	As above, meter selector to mic.	Deviation: VHF, UHF, and 800MHz: ≥ 3.6kHz but ≤ 5.0kHz. 900MHz: ≥ 1.8kHz but ≤ 2.5kHz.
Low-Speed Data Modulation 800 UHF	As above	TEST MODE Test Channel 4 trunking low speed output at antenna	PTT to continuous (during the performance check).	Deviation: 800MHz: ≥ 500Hz but ≤ 1000Hz.
Voice Modulation (internal)	Mode: PWR MON 4th channel test frequency* attent to –70, input to RF In / Out.	TEST MODE, Test Channel 4 carrier squelch output at antenna	Remove modulation input.	Press PTT switch on radio. Say "four" loudly into the radio mic. Measure deviation: VHF, UHF, and 800MHz: ≥ 3.8kHz but ≤ 5.0kHz. 900MHz: ≥1.9kHz but ≤ 2.5kHz.
High-Speed Data Modulation***	As above.	TEST MODE, Test Channel 4 trunking high speed output at antenna	PTT to continuous (during the performance check).	Deviation: 800MHz: ≥ 2.4kHz but ≤ 3.6kHz. 900MHz: ≥ 1.2kHz but ≤ 1.75kHz.
DTMF Modulation	As above, 4th channel test frequency*	TEST MODE, Test Channel 4 DTMF output at antenna	As above.	Deviation: VHF, UHF, and 800MHz: ≥ 3.8kHz but ≤ 5.0kHz. 900MHz: ≥ 1.9kHz but ≤ 2.5kHz.
PL / DPL Modulation	As above, 4th channel test frequency* BW to narrow.	TEST MODE, Test Channel 4 TPL DPL	As above.	Deviation: VHF, UHF, and 800MHz: ≥ 500Hz but ≤ 1000Hz. 900MHz: ≥ 250Hz but ≤ 500Hz.

***Trunked Only

*See Table 4-3

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Section 5
Radio Alignment Procedure

General

An IBM personal computer (PC) and radio service software (RSS) are required to align the radio. Refer to the applicable RSS manual for installation and setup procedures for the software. To perform the alignment procedures, the radio must be connected to the PC, radio interface box (RIB), and universal test set as shown in Figure 5-1.

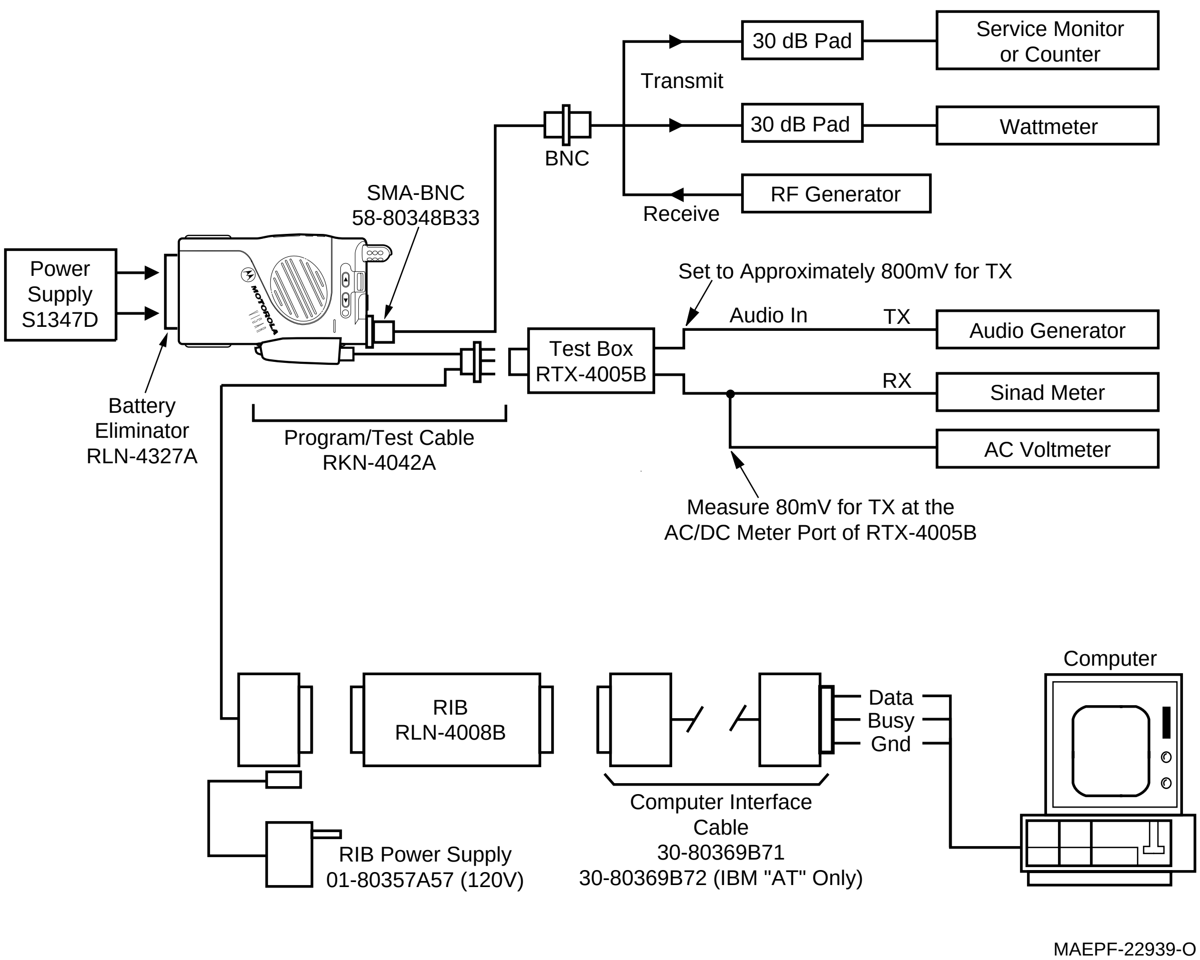

Figure 5-1. Radio Alignment Test Setup

All service and tuning procedures are performed from the SERVICE menu, which is selected by pressing F2 from the MAIN MENU. Figure 5-2 illustrates how the RSS SERVICE screens are organized.

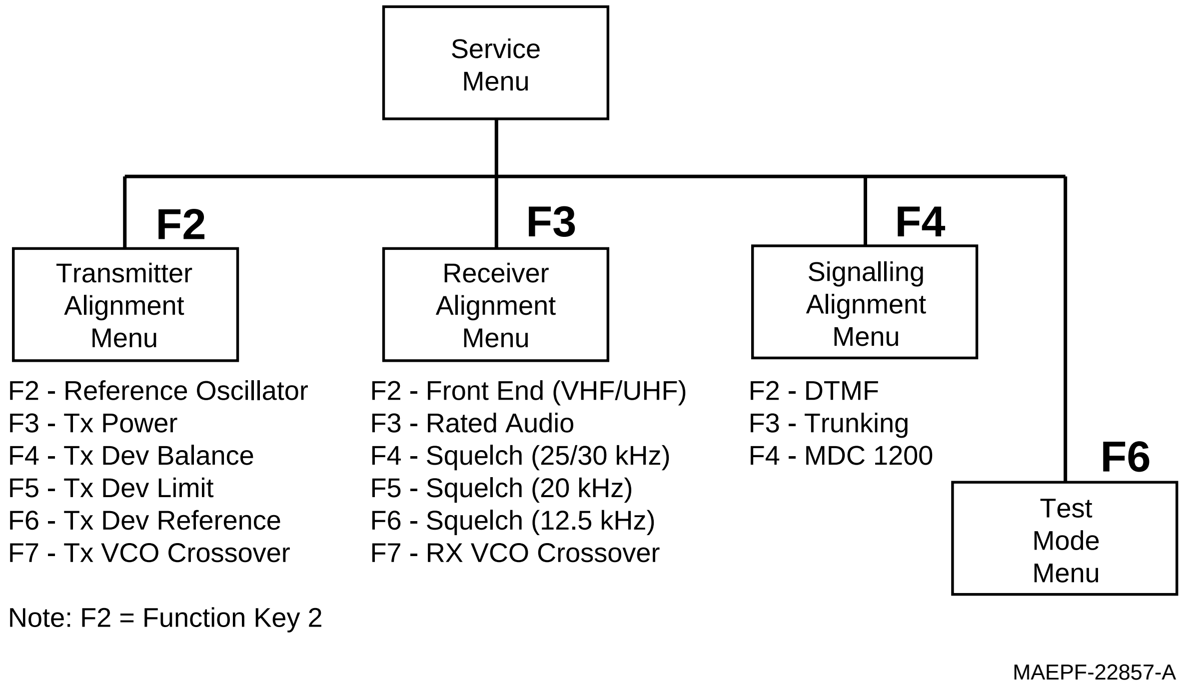

Figure 5-2. RSS Service Menu Layout

All SERVICE screens read and program the radio codeplug directly; you do NOT have to use the RSS GET/SAVE functions to use the SERVICE menus. You will be prompted at each screen to save changed values before exiting the screen.

CAUTION

Do NOT switch radios in the middle of any SERVICE procedure. Always use the EXIT key to return to the MAIN menu screen before disconnecting the radio. Improper exits from the SERVICE screens may leave the radio in an improperly configured state and result in seriously degraded radio or system performance.

The radio contains internal test modes that can be accessed from the RSS. The test modes permit the service technician to easily select various frequency, modulation, and transmit power combinations to verify proper operation of the radio. The test modes can be used to check both transmit and receive operation. Press F2 (SERVICE) from the Main Menu, and then press F6 to navigate to the TEST MODE screen.

The SERVICE screens introduce the concept of the "softpot," an analog SOFTware controlled POTentiometer used for adjusting all transceiver alignment controls.

Each SERVICE screen provides the capability to increase or decrease the 'softpot' value with the keyboard UP/DOWN arrow keys respectively. A graphical scale is displayed indicating the minimum, maximum, and proposed value of the softpot, as shown in Figure 5-3.

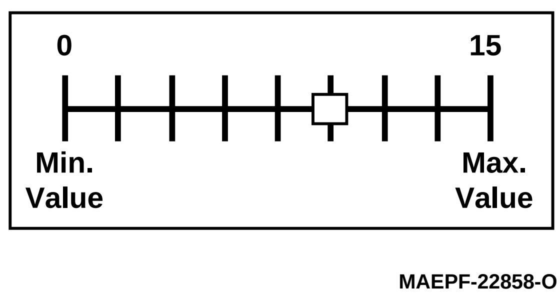

Figure 5-3. Softpot Concept

Adjusting the softpot value sends information to the radio to increase (or decrease) a dc voltage in the corresponding circuit. For example, pressing the UP arrow key at the Reference Oscillator screen instructs the radio microprocessor to increase the voltage across a varactor in the reference oscillator.

In ALL cases, the softpot value is just a relative number corresponding to a digital-to-analog (D/A) generated voltage in the radio. All standard measurement procedures and test equipment are similar to previous radios.

Perform the following procedures in the indicated sequence:

Reference Oscillator Alignment

Adjustment of the reference oscillator is critical for proper radio operation. Improper adjustment will not only result in poor operation, but also a misaligned radio that will interfere with other users operating on adjacent channels. For this reason, the reference oscillator should be checked every time the radio is serviced. The frequency counter used for this procedure must have a stability of 0.1 ppm, or better.

1. From the SERVICE menu, press F2 to select TRANSMITTER alignment.
2. Press F2 again to select the REFERENCE OSCILLATOR softpot.
3. Press F6 to key the radio. The screen will indicate that the radio is transmitting.
4. Measure the transmit frequency on your service monitor.
5. Use the UP/DOWN arrow keys to adjust the reference oscillator per the targets shown in Table 5-1.

Table 5-1. Reference Oscillator Alignment

Band	Target
VHF	± 150Hz
UHF	± 150Hz
800MHz	± 150Hz

6. Press F6 again to dekey the radio.
7. Press F8 to program the softpot value; press F10 - F2 - F10 to return to the SERVICE menu.

Front-End Pre-Selector (VHF/UHF Only)

NOTE
This procedure is only required for tuning the front-end filter varactors in the VHF and UHF models. The 800MHz models utilize a stripline pre-selector.

1. Set the test box (RTX4005B) meter selection switch to the “VOL” position, and connect a dc voltmeter capable of 1mV resolution on a 2V scale to the test box AC/DC mtr port to monitor the received signal strength Indicator (RSSI).
2. From the SERVICE menu, press F3 to select RECEIVER alignment.
3. Press F2 to select the FRONT END FILTER softpot. The screen will indicate the receive frequencies at which the filter is to be tuned.
4. Set the RF test generator to the first receive frequency of ±150Hz. Set the RF level at the radio standard antenna port to 4.0 µV with no modulation.
5. Adjust the UP/DOWN arrow keys to obtain a peak voltage on the dc voltmeter.
6. Press F8 to program the softpot value.
7. Repeat steps 4-6 for the remaining test frequencies.
8. Press F10 and F2 to return to the RECEIVER menu.

Rated Audio

1. Set the test box (RTX-4005B) meter selection switch to the “AUDIO PA” position, and connect an ac voltmeter to the test box ac/dc meter port.
2. Press F3 to select the RATED AUDIO softpot. The screen will indicate the receive test frequency to be used.
3. Set the RF test generator to the receive test frequency, and set the RF level at the radio standard antenna port to 1mV modulated with standard test modulation. (See Table 5-2 below.)

Table 5-2. Standard Test Modulation (1kHz Tone)

Channel Spacing	Deviation
25/30kHz	3.0kHz
20kHz	2.4kHz
12.5kHz	1.5kHz

4. Adjust the UP/DOWN arrow keys to obtain a rated audio (as close to 3.74 Vrms) into a speaker with 28 ohms, or equivalent, resistive load.
5. Press F8 to program the softpot value.
6. Press F10 to return to the RECEIVER menu.

Squelch

1. Press F4, F5, or F6 to select the SQUELCH softpot.
2. With no signal applied, decrease the softpot value until squelch opens. Set the RF test generator to the test frequency plus the following offset:

   VHF +200Hz; UHF +200Hz; 800MHz +500Hz.

   Adjust the generator for 8—10 dB SINAD.
3. Increase the softpot until the squelch closes.

4. Monitor for squelch chatter. If chatter is present, increase the softpot until no chatter is detected. Press F8 to program the softpot value. Press ENTER to select the next softpot adjustment.
5. Repeat steps 2 through 4 for all test frequencies shown on the screen.
6. Press F10, F2, then F10 to return to the SERVICE menu.

Transmitter Power

VHF and UHF radios require two power-level adjustments: a high-power or rated-power adjustment, and a low-power adjustment. The low power adjustment is required since the radio may be used in a reduced power mode.

NOTE
All power measurements are to be made at the antenna port.

1. From the SERVICE menu, press F2 to select TRANSMITTER alignment.
2. Press F3 to select the TRANSMIT POWER softpot. The screen will indicate the transmit test frequencies to be used.
3. Begin with the highest test frequency shown.
4. Press F6 to key the radio, and use the UP/DOWN arrow keys to adjust the transmit power to the value shown in Table 5-3.
5. Press F6 to dekey the radio, and then press F8 to program the value. Press ENTER to select the next softpot value.
6. Repeat steps 4-5 for the remaining test frequencies.
7. Press F10, then F2 to return to the TRANSMIT menu.

Transmit Deviation Balance (Compensation)

Compensation alignment balances the modulation sensitivity of the VCO and reference modulation (synthesizer low-frequency port) lines. The compensation algorithm is critical to the operation of signalling schemes that have very low frequency components (for example, DPL), and could result in distorted waveforms if improperly adjusted.

1. Press F4 to select the TRANSMIT DEVIATION BALANCE softpot. The screen will indicate the transmit test frequencies to be used.
2. Begin with the lowest test frequency shown on the screen.
3. Set the test box (RTX4005B) meter selector switch to the “MX DISC” position, and inject an 80Hz tone at 100 mVrms into the AC/DC MTR port. Keep the ac voltmeter in parallel to insure the proper input signal level.
4. Press F6 to key the radio, and measure deviation. Record this level.
5. Change the input tone to 3kHz, 100 mVrms and use the UP/DOWN arrow keys to adjust the deviation to within ±2% of the value recorded in step 4.
6. Change the input tone back to 80Hz and measure the deviation.
7. Repeat steps 5 and 6 until the 3kHz tone deviation is within ±2% of the 80Hz tone deviation.
8. Press F6 to dekey the radio, and press F8 to program the softpot value. Press ENTER to move to the next softpot value.
9. Repeat steps 3-8 for the remaining test frequencies.
10. Press F10 to return to the TRANSMIT menu.

NOTE
The step size change for step 5 is approximately 2.5% per softpot value. Do NOT adjust the softpot for 80Hz; adjust only for 3.0kHz deviation.

Table 5-3. Transmit Power Setting

VHF			UHF		
	Test Frequencies			Test Frequencies	
Power Level	**136-174MHz**	**177.975MHz**	**Power Level**	**450-512MHz**	**512-520MHz**
5 W	5.2 - 5.4	177.975MHz	4 W	4.2 - 4.4	3.2 - 3.4
1 W	1.2 - 1.4	1.2 - 1.4	1 W	1.2 - 1.4	1.2 - 1.4

800MHz	
Power Level	**All Test Frequencies**
3 W	3.20-3.40

Transmit Deviation Limit

1. Press F5 to select the TRANSMIT DEVIATION LIMIT softpot. The screen will indicate the transmit test frequencies to be used.
2. Begin with the lowest test frequency shown on the screen.
3. With the meter selector switch (RTX4005B) set to MIC, inject a 1kHz tone on the AUDIO IN terminal on the test set (80mVrms as measured on the AC/DC MTR port).
4. Press F6 to key the radio, and use the UP/DOWN arrow keys to adjust the deviation per the values shown in Table 5-4.

Table 5-4. Transmit Deviation Limit

Band	Deviation (KHz)
VHF/UHF/800MHz	4.4 - 4.60

5. Press F6 to dekey the radio, and press F8 to program the softpot value. Press ENTER to select the next softpot value.
6. Repeat steps 3-5 for the remaining frequencies shown on the screen.
7. Press F10 to return to the TRANSMIT menu.

Transmit Deviation Limit Reference

NOTE
This procedure is required for VHF, UHF, and 800MHz models with 20kHz channel spacing and VHF and UHF models with 12.5kHz channel spacing.

1. Press F6 to select the TRANSMIT DEVIATION LIMIT REFERENCE softpot.
2. With the meter selector switch (RTX4005B) set to MIC, inject a 1kHz tone on the AUDIO IN terminal on the test set (80mVrms as measured on the AC/DC MTR port).
3. Press F6 to key the radio, and use the UP/DOWN arrow keys to adjust the deviation per Table 5-5.

Table 5-5. Transmit Deviation Limit Reference

Channel Spacing	Deviation (kHz)
20 KHz	3.40 - 3.60
12.5 KHz	2.20 - 2.30

4. Press F6 to dekey the radio, and press F8 to program the softpot value.
5. Press F10 to return to the TRANSMIT menu.

VCO Crossover Frequency

NOTE
This procedure is only required after the field repair of a VHF or UHF VCO.

In order for a phase-locked loop to tune very wide bandwidths, both negative and positive control voltages (Vcntl) are required. This procedure sets the crossover frequency at which the negative Vcntl (or –Vee) switches from zero to negative.

TX VCO Crossover

1. From the SERVICE menu, press F2 to select TRANSMITTER alignment.
2. Press F7 to select the TRANSMIT VCO CROSSOVER softpot. The screen will indicate the transmit test frequency to be used.
3. Connect a dc voltmeter capable of 1mV resolution to test point 5 (TP5); TP5 is accessible through a hole in the bottom side of the VCO circuitry shield.
4. Beginning with the default softpot frequency of line 2, press F6 to key the transmitter, and use the UP/DOWN arrow keys to adjust the softpot until the voltage reading at TP5 is 3.0 ±0.1 volts. The frequency will increment in steps of 50kHz.
5. Press F6 again to dekey the transmitter, and press F8 to program the softpot value.
6. Press F10 twice to return to the SERVICE menu.

RX VCO Crossover

1. From the SERVICE menu, press F3 to select RECEIVER alignment.
2. Press F5 to select the RECEIVE VCO CROSSOVER softpot. The screen will indicate the receive test frequency to be used.
3. Connect a dc voltmeter capable of 1mV resolution to test point 5 (TP5); TP5 is accessible through a hole in the bottom side of the VCO circuitry shield.
4. Beginning with the default softpot frequency of line 2, use the UP/DOWN arrow keys to adjust the softpot until the voltage reading at TP5 is 3.0 ±0.1 volts.
5. Press F8 to program the softpot value.
6. Press F10 twice to return to the SERVICE menu.

Signalling Deviation

Complete the transmit deviation balance (compensation) and transmit deviation limit adjustments before adjusting the signalling deviation.

DTMF Tuning

1. From the SERVICE menu, press F4 to select SIGNALLING alignment.
2. Press F2 again to select the DTMF softpot.
3. Press F6 to key the radio on the test frequency. The screen will indicate that the radio is transmitting.
4. Measure the DTMF deviation on your service monitor.
5. Use the UP / DOWN arrow keys to adjust the DTMF deviation per Table 5-6.
6. Press F6 again to dekey the radio.
7. Press F8 to program the softpot value; press F10 to return to the SIGNALLING menu.

High-Speed Trunking Signalling (Privacy Plus Models Only)

1. From the SERVICE menu, press F4 to select SIGNALLING alignment.
2. Press F3 to select the TRUNKING HIGH SPEED softpot.
3. Press F6 to key the radio on the test frequency. The screen will indicate that the radio is transmitting.
4. Measure the TRUNKING HIGH SPEED deviation on your service monitor.
5. Use the UP / DOWN arrow keys to adjust the TRUNKING HIGH SPEED deviation per Table 5-6.
6. Press F6 again to dekey the radio.
7. Press F8 to program the softpot value; press F10 to return to the SIGNALLING menu.

MDC 1200

1. From the SERVICE menu, press F4 to select SIGNALLING alignment.
2. Press F4 to select the MDC softpot.
3. Press F6 to key the radio on the test frequency. The screen will indicate that the radio is transmitting.
4. Measure the MDC deviation on your service monitor.
5. Use the UP / DOWN arrow keys to adjust the MDC deviation per Table 5-6.
6. Press F6 again to dekey the radio.
7. Press F8 to program the softpot value; press F10 twice to return to the SERVICE menu.

Single Tone™ Tuning

1. From the SERVICE menu, press F4 to select SIGNALLING alignment.
2. Press F5 to select the SINGLETONE softpot.
3. Press F6 to key the radio on the text frequency. The screen will indicate the radio is transmitting.
4. Measure the SINGLETONE deviation on your service monitor.
5. Use the UP / DOWN arrow keys to adjust the SINGLETONE deviation per Table 5-6.
6. Press F6 again to dekey the radio.
7. Press F8 to program the softpot value. Press F10 to return to the SIGNALLING menu.

The radio alignment procedure is now complete; the radio may be disconnected and returned to service.

Table 5-6. Signalling Deviation

Channel Spacing (kHz)	DTMF	Trunking	MDC	SingleTone
25 / 30	3.05-3.45	2.5-3.5	3.25-3.75	3.0-4.0
20 (VHF / UHF)	2.44-2.76	2.0-2.8	2.6-3.0	2.4-3.2
20 (821-824, 866-869)	2.44-2.76	2.0-2.8	2.6-3.0	2.4-3.2
12.5	1.55-1.85	1.25-1.75	1.625-1.875	1.5-2.0

Section 6
Radio Cloning Information

General Information

- Cloning duplicates the contents of radio 1 (source radio) into radio 2 (target radio). Tuning and alignment information are not affected by cloning.
- Radios to be cloned must have the identical model number and be equipped with the same software options. Radio functionality inherent in one radio cannot be cloned to another radio that does not contain the same functionality.

NOTE
The VISAR Privacy Plus model radios do not support radio-to-radio cloning.

- An attempt to clone radios that are not of the same model number or software options will result in an error indication, but an unsuccessful attempt will not damage the radio.
- VHF DN models cannot be cloned to AN, BN, or CN models.
- Any DN model can be cloned from like CN or DN models.
- The scan and battery-saver capabilities of the CN or DN model radio could be seriously degraded by failing to perform a code plug fix on the AN or BN model prior to cloning into a like CN or BN model.

NOTE
Cloning any AN model into a like CN or DN model will remove the TEST MODE capability.

- MDC and Star IDs (Identification Numbers) are duplicated in the cloning process. Unique IDs may be assigned with the radio service software.

Procedure

1. Turn both radios off by rotating the volume control knob fully counterclockwise.
2. Plug the cloning cable (RKN4043A) into the side connectors of both radios with the cable toward the top of the radios.
3. Turn on radio 2 (target radio) by rotating the volume control clockwise.
4. **Simultaneously** press the PTT and side button 2 (side button nearest the PTT) on radio 1 (source radio), and then turn radio 1 on.
5. The green LED on both radios will light, and display-equipped radios will display “CL.” At this point, release the PTT and side button 2.
6. The cloning process is complete when the green LEDs turn off. The radios will turn off and on automatically (that is, they will “reset”), and then return to normal operation.

NOTE
Cloning will take approximately five seconds.

7. Disconnect the cloning cable, and the radios are ready for operation.

Error Conditions

An unsuccessful cloning attempt will be indicated by radio 1 (source radio) not resetting, and the display continuing to show “CL.” Radio 1 must be reset by turning it off and on. Unsuccessful cloning attempts may result under one of the following conditions:

1. Communication cannot be established between the radios. If this occurs, the cloning cable should be checked to verify that it is properly connected to both radios. Check the cable's integrity. Radio 2 (target radio) should also be checked to verify that it is turned on. Return to section B, step 1 (this page) and repeat the procedure.
2. The model numbers or the software options are not the same. Cloning cannot be performed in these cases.
3. Communication between the two radios is disrupted during the cloning process. If this occurs, check the cloning cable and all connections. Return to section B, step 1 (this page) and repeat the procedure.

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Section 7
Disassembly and Reassembly

CAUTION

This radio contains static-sensitive devices. Do not open the radio unless properly grounded. Take the following precautions when working on this unit:

1. Store and transport all complementary metal-oxide semiconductor (CMOS) devices in conductive material so that all exposed leads are shorted together. Do not insert CMOS devices into conventional plastic “snow” trays used for storage and transportation of other semiconductor devices.
2. Ground the working surface of the service bench to protect the CMOS device. We recommend using the Motorola Static Protection Assembly (part number 0180386A82), which includes a wrist strap, two ground cords, a table mat, and a floor mat.
3. Wear a conductive wrist strap in series with a 100k resistor to ground. Replacement wrist straps that connect to the bench top covering are Motorola part number RSX-4015.
4. Do not wear nylon clothing while handling CMOS devices.
5. Neither insert nor remove CMOS devices with power applied. Check all power supplies that are to be used for testing CMOS devices to be certain that there are no voltage transients present.
6. When straightening CMOS pins, provide ground straps for apparatus used.
7. When soldering, use a grounded soldering iron.
8. If at all possible, handle CMOS devices by the package and not by the leads. Prior to touching the unit, touch an electrical ground to remove any static charge that you may have accumulated. The package and substrate may be electrically common. If so, the reaction of a discharge to the case would cause the same damage as touching the leads.

General

Since this product may be disassembled and reassembled without the use of any screws, it becomes important for the technician to pay particular attention to the snaps and tabs, and how parts align with each other.

NOTE

In the disassembly / reassembly procedure, the numbers in parentheses refer to call-out numbers in the referenced figures.

Disassembly to Board Level

1. Turn off the radio.
2. Remove the battery as follows: (See Figure 7-1)

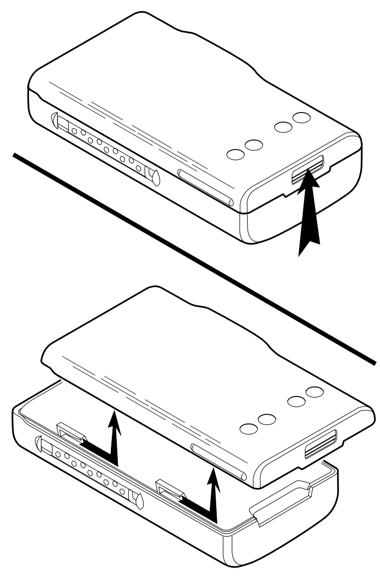

Figure 7-1.

2A. Hold the radio with the front in the palm of your hand.

2B. With the thumb of your other hand, use the finger grooves to slide the latch at the bottom of the battery toward the back of the battery.

2C. While holding the latch up, slide the battery down toward the bottom of the radio.

2D. Separate the battery from the radio.

3. Turn the antenna in a counterclockwise direction to loosen it. Remove it from the radio.

4. Remove the volume on / off knob by pulling it off its switch shaft.

NOTE

- The knob slides on and off, but fits very snugly on its switch shaft. A small flat-blade screwdriver may be necessary to help pry the knob loose. Take care not to mar the surrounding radio surface.
- If the potentiometer or controls flex is not being removed, you do not need to remove the volume knob for radio disassembly.

5. Separate the front cover assembly from the internal electronics (chassis) as follows: (See Figure 7-2)

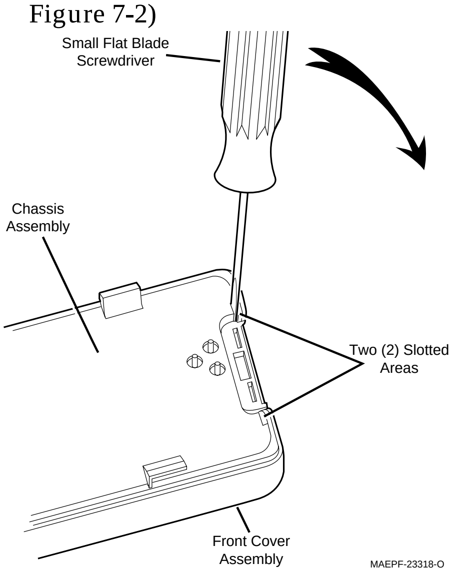

Figure 7-2.

5A. Insert a small, flat-blade screwdriver (or similar instrument) into one of the slotted areas at the bottom of the radio. Take care not to mar the O-ring sealing area on the housing.

5B. Pry the bottom of the chassis free from the cover by pushing the screwdriver down and rotating its handle over and behind the base of the radio. The prying action forces the thin, plastic wall of the radio away from the two chassis base tabs. This releases the chassis assembly from the front cover assembly.

5C. Insert the screwdriver into the other slotted area, and pry the chassis until it completely releases from the front-cover assembly.

NOTE

A flexible ribbon cable (transceiver board / controller interconnect flex) keeps the two units from completely separating.

5D. Lay the chassis down and rotate the front cover back and partially away from the chassis. (See Figure 7-3)

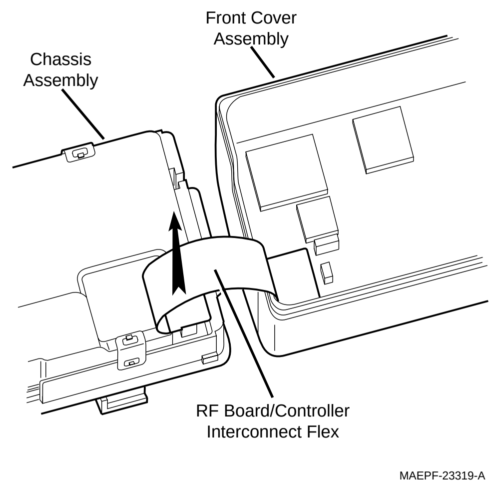

Figure 7-3.

6. Disconnect the interconnect flex from the connector on the chassis.

NOTE

Do not pull on the flex circuit loop. Use the top of the 20-pin connector for removal.

7. Remove the contoured O-ring / antenna bushing seal from the chassis.

8. Separate the front shield from the chassis and circuit boards. (See Figure 7-4)

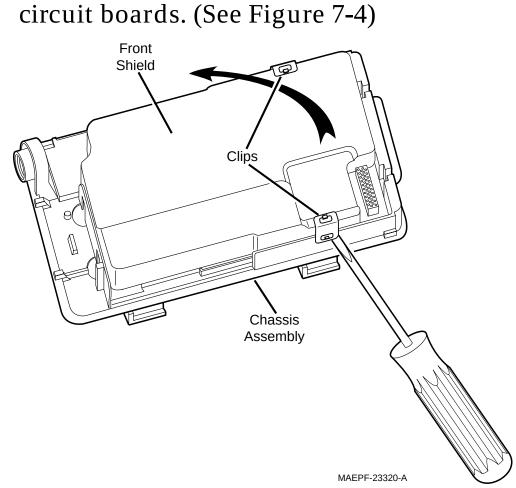

Figure 7-4.

NOTE

Two large clips secure the front shield to the chassis and hold the transceiver board in the chassis.

Loosen the front shield by prying each of the two clips away from the chassis. Then, rotate the shield up and around the top edge.

9. Carefully remove the transceiver board from the chassis (see Figure 7-5).

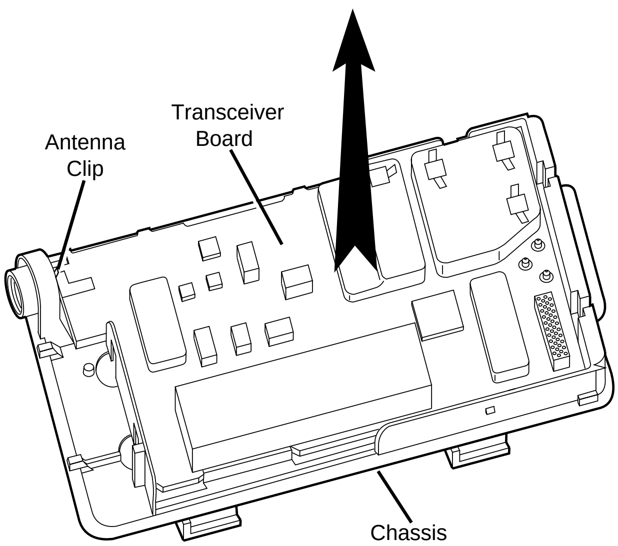

Figure 7-5.

NOTE

Do not snag or over-bend the antenna clip.

Disassembly of Front Cover

1. Remove the retaining clip, located just below the speaker, by sliding it toward the side button assembly.

2. Release the display module from the front cover. Lightly push down and rotate the display module away from the housing.

3. Before removing the controller printed circuit board, be sure the jack cover seal is removed. Take out the controller board by placing the blade of a small flat-blade screwdriver into the pry slot at the base of the radio; gently lift the board past the two housing tabs in the base. Take care not to overly deflect the circuit board. See Figure 7-6 and Figure 7-7.

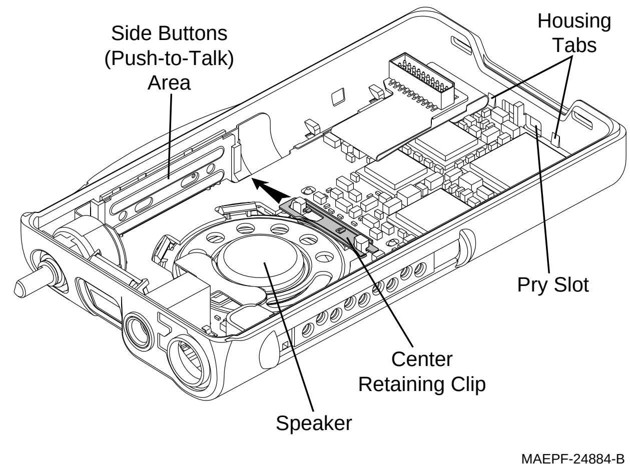

Figure 7-6.

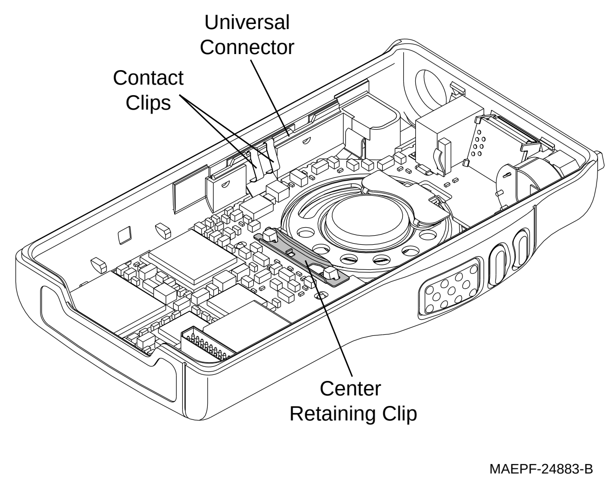

Figure 7-7.

NOTE

While removing the controller board, avoid the universal connector back plate contact clips. These contact clips could be damaged if care is not used.

Once you lift the controller board past the housing tabs, turn the front cover up-side-down; the board should drop easily.

4. Pull the controller board out and away from the housing.

NOTE

The jack and the display module are attached to the controller board. Therefore, the board must be removed at an angle to release the jack and the display from the front cover.

5. Remove the universal connector backer plate by sliding it out of the plastic rails that hold it in place. You might achieve better results by using a flat-blade screwdriver to pry the backer plate out. Use care not to mar the surrounding surfaces.

NOTE
A second tool might be needed to bow the back wall away from the wedge barbs.

6. Remove the push-to-talk (PTT) backer plate by sliding it out of the plastic rails that hold it in place. Again, better results might be achieved using the corner of a flat-blade screwdriver under the rib.

! CAUTION
Do not use the breather holes for leverage. This will damage the flex circuit.

7. Disengage the speaker by deflecting the retaining tabs outward, and rotate the speaker out and up (see Figure 7-8).

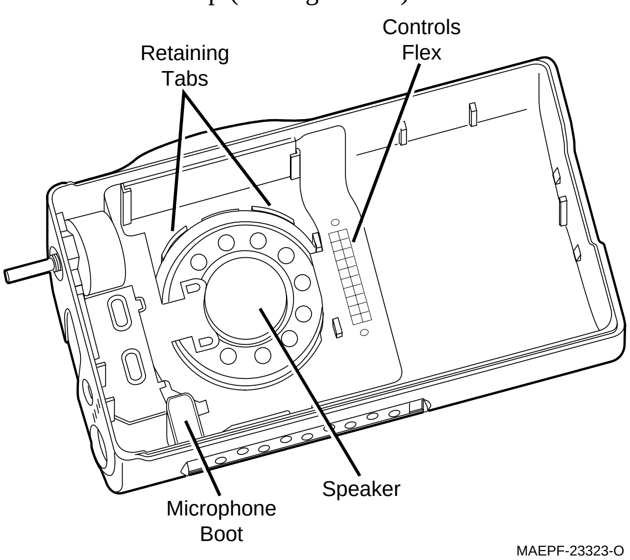

Figure 7-8.

8. Pull the rubber microphone boot containing the microphone from its seated position. Unless you are replacing the microphone, leave the microphone in the boot.

9. After you pull the flex circuit connecting the potentiometer with the speaker away from the front cover, you can easily remove the volume control potentiometer from its assembly to the front cover. Taking care not to damage the flex circuit, place a screwdriver blade between the flex circuit and the front cover. Gently pull the flex free from the PTT backer plate rail. This will allow the potentiometer to fall out of the hole.

10. If necessary, replace the speaker, microphone, or volume potentiometer while they are removed from the front cover housing.

NOTE
If the microphone is replaced, be sure the microphone is reinstalled back into the rubber boot, with the microphone port facing the round hole at the bottom of the boot, and the flex circuit going through the gate.

Reassembly

Reassembly is the reverse of disassembly.

Front Cover Assembly

1. Reassemble the volume control potentiometer and the attached flex circuit to the front cover assembly. Gently guide the potentiometer into the hole in the front cover until the small tab engages the recess in the housing. A white indicator line on the bottom of the potentiometer will point to 12 o'clock when correctly installed. After you have correctly reassembled the potentiometer, place the flex circuit (the piece that runs from the potentiometer to the speaker) flat against the wall of the plastic housing — inside the front cover, just above the PTT backer plate plastic rail. A small flex circuit tab should extend straight out of the assembly, parallel to the white indicator line. This tab should move freely; it will be folded in against the potentiometer when the front cover and chassis are reassembled.

2. Place the speaker in the front cover. Make sure that the speaker is seated properly in the recessed area and snapped into the retaining tabs.

3. Press the rubber microphone boot into its recessed area in the front cover housing.

NOTE
Check to see if the frequency keypad, the 20-pin pressure pad, and all underlying components are in place and properly located before replacing the controller.

4. Angle the controller into the front cover. Be certain that the top of the board slips between the two rails in the top of the housing, and that the jack and the LCD are aligned in their slots. Snap the rear of the board under the housing tabs at the base. Slide the center retaining clip into place.

⚠ CAUTION

When installing the center clips, be careful not to damage the retaining clip posts. Apply force above the 20-pin area while sliding the retaining clip.

Chassis

Inside of the chassis, where the transceiver board fits, is a protruding block that functions as the PA heatsink. To help provide maximum heat transfer, make sure that the PA heatsink block (top surface) is covered with a thermal pad (Motorola part number 7505922Z01).

NOTE

Check to see if the pogo-pin seal is properly installed.

Place the transceiver board into the chassis.

Control Top/Front Shield/Controls Flex as a Unit to Chassis.

1. Place the front shield into position over the chassis and circuit board by hinging it at the top.

NOTE

Check to see if all the shield walls are located inside the chassis and the dimples are making contact.

2. Snap the front shield into place with the two clips. Be sure that the shield is fully seated, especially in the PTT switch area.

Front Cover Assembly to Chassis

1. Install the contoured O-ring / antenna bushing seal around the antenna and in the groove provided (see Figure 7-9).

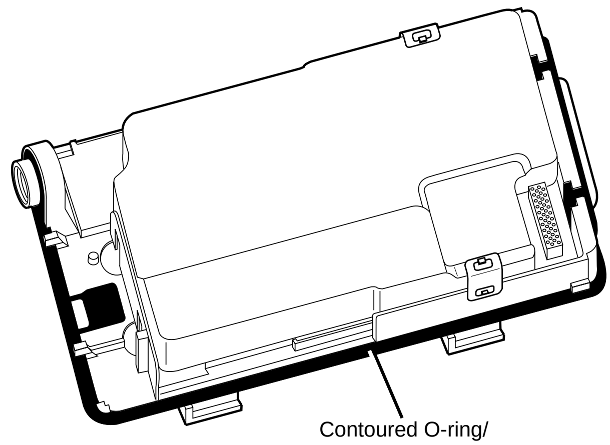

Figure 7-9.

2. Align the front-cover assembly with the chassis, and insert the interconnect flex into the 20-pin connector on the chassis.

3. Check to make sure that the O-ring is in place, and that the flex circuit extension tab on the volume potentiometer is folded down against the potentiometer. Slide the chassis (antenna bushing first) into the front cover assembly.

NOTE

When performing the next part of this step, pay particular attention to the O-ring near the bottom of the radio. Make sure the O-ring does not raise up and get pinched between the front-cover clip and the chassis. With the top of the chassis fully seated, lower the bottom of the chassis, pressing it into the front-cover assembly until it snaps into place.

4. Reinstall the volume knob and antenna.

5. Reinstall the battery.

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Section 8
Maintenance

Introduction

This section of the manual describes preventive maintenance, safe handling of CMOS devices, and repair procedures and techniques. Each of these topics provides information vital to the successful operation and maintenance of your radio.

Preventive Maintenance

VISAR radios do not require a scheduled preventive maintenance program; however, periodic visual inspection and cleaning is recommended.

Inspection

Check that the external surfaces of the radio are clean, and that all external controls and switches are functional. A detailed inspection of the interior electronic circuitry is neither needed nor desired.

Cleaning

The following procedures describe the recommended cleaning agents and the methods to be used when cleaning the external and internal surfaces of the radio. External surfaces include the front cover, housing assembly, and battery case. These surfaces should be cleaned whenever a periodic visual inspection reveals the presence of smudges, grease, and/or grime. Internal surfaces should be cleaned only when the radio is disassembled for servicing or repair.

The only recommended agent for cleaning the external radio surfaces is a 0.5% solution of a mild dishwashing detergent, such as JOY®, in water. The only factory recommended liquid for cleaning the printed circuit boards and their components is isopropyl alcohol (70% by volume).

⚠ CAUTION

The effects of certain chemicals and their vapors can have harmful results on certain plastics. Aerosol sprays, tuner cleaners, and other chemicals should be avoided.

Cleaning External Plastic Surfaces

The detergent-water solution should be applied sparingly with a stiff, non-metallic, short-bristled brush to work all loose dirt away from the radio. A soft, absorbent, lintless cloth or tissue should be used to remove the solution and dry the radio. Make sure that no water remains entrapped near the connectors, cracks, or crevices.

Cleaning Internal Circuit Boards and Components

Isopropyl alcohol may be applied with a stiff, non-metallic, short-bristled brush to dislodge embedded or caked materials located in hard-to-reach areas. The brush stroke should direct the dislodged material out and away from the inside of the radio.

Alcohol is a high-wetting liquid and can carry contamination into unwanted places if an excessive quantity is used. Make sure that controls or tunable components are not soaked with the liquid. Do not use high-pressure air to hasten the drying process, since this could cause the liquid to puddle and collect in unwanted places.

Upon completion of the cleaning process, use a soft, absorbent, lintless cloth to dry the area. Do not brush or apply any isopropyl alcohol to the frame, front cover, or back cover.

NOTE

Always use a fresh supply of alcohol and a clean container to prevent contamination by dissolved material (from previous usage).

Safe Handling of CMOS Devices

Complementary metal-oxide semiconductor (CMOS) devices are used in this family of radios. While the attributes of CMOS are many, their characteristics make them susceptible to damage by electrostatic or high voltage charges. Damage can be latent, resulting in failures occurring weeks or months later. Therefore, special precautions must be taken to prevent device damage during disassembly, troubleshooting, and repair. Handling precautions are mandatory for CMOS circuits and are especially important in low humidity conditions. DO NOT attempt to disassemble the radio without first referring to the CMOS CAUTION paragraph in the Disassembly and Reassembly section of the manual.

Repair Procedures and Techniques

Refer to the Disassembly and Reassembly section of the manual for pertinent information prior to replacing and substituting parts.

General

Parts Replacement and Substitution

Special care should be taken to be as certain as possible that a suspected component is actually the one at fault. This special care will eliminate unnecessary unsoldering and removal of parts, which could damage or weaken other components or the printed circuit board itself.

When damaged parts are replaced, identical parts should be used. If the identical replacement component is not locally available, check the parts list for the proper Motorola part number and order the component from the nearest Motorola Communications Parts office listed in the “Replacement Parts Ordering” section of this manual.

Rigid Circuit Boards

This family of radios uses bonded, multi-layer, printed circuit boards. Since the inner layers are not accessible, some special considerations are required when soldering and unsoldering components. The printed-through holes may interconnect multiple layers of the printed circuit. Therefore, care should be exercised to avoid pulling the plated circuit out of the hole.

When soldering near the 20-pin connector, use care to avoid accidentally getting solder in the connector. Also, be careful not to form solder bridges between the connector pins. Closely examine your work for shorts due to solder bridges.

Flexible Circuits

The flexible circuits are made from a different material than the rigid boards, and different techniques must be used when soldering. Excessive prolonged heat on the flexible circuit can damage the material. Avoid excessive heat and excessive bending. For parts replacement, use the ST-1087 Temperature-Controlled Solder Station with a 600 or 700 degree tip, and use small diameter solder such as ST-633. The smaller size solder will melt faster and require less heat being applied to the circuit.

To replace a component on a flexible circuit, grasp the edge of the flexible circuit with seizers (hemostats) near the part to be removed, and pull gently. Apply the tip of the soldering iron to the component connections while pulling with the seizers. Do not attempt to puddle out components. Prolonged application of heat may damage the flexible circuit.

Specific

Interconnect Flex

Because the interconnect flex solders to the controller board much like a surface mounted component, similar cautions and procedures should be followed for repair and replacement of this part. To remove the flex, use a heat-focus head or similar heat-spreading device to uniformly heat 20 flex feed-thru holes (interconnect flex side) on the controller board. Hot air temperature should not exceed 450 degrees F.

Once all of the solder on the heated side is molten, lift the flex up gently, taking care not to peel runners from the rigid board due to unmelted solder joints.

On the circuit board, reflow any remaining solder on the 20 pads to ensure that each pad has roughly the same amount of solder. Add or remove solder from individual pads as required. A small dome of solder needs to reside on each pad. A pad that appears very flat, as if little or no solder is present, should have additional solder added. Once the solder is distributed evenly, apply a small amount of flux to all the pads.

Align the new flex to the controller board using the alignment holes in the board and corresponding holes in the flex. Using the same heat-focus head, or similar heat-spreading device as used in desoldering the flex, solder the flex to the controller board. Apply gentle pressure on the top surface of the flex during heating to be certain that all the 20 tabs solder. The solder, wicking up through the flex feed-thru holes, is a visual indication that a good joint is being made. Some solder joints may need to be “touched-up.” Reflow these joints using a small-tipped soldering iron, taking care not to burn the flex.

Chip Components

Use either the RLN-4062 Hot-Air Repair Station or the Motorola 0180381B45 Repair Station for chip component replacement. When using the 0180381B45 Repair Station, select the TJ-65 mini-thermojet hand piece. On either unit, adjust the temperature control to 700 degrees F. (370 degrees C.), and adjust the airflow to a minimum setting. Airflow can vary due to component density.

1. **To remove a chip component**, select a hot-air hand piece and position the nozzle of the hand piece approximately 1/8” above the component to be removed. Begin applying the hot air. Once the solder reflows, remove the component using a pair of tweezers. Using solder wick and a soldering iron or a power desoldering station, remove the excess solder from the pads.

2. **To replace a chip component using a soldering iron**, select the appropriate micro-tipped soldering iron and apply fresh solder to one of the solder pads. Using a pair of tweezers, position the new chip component in place while heating the fresh solder. Once solder wicks onto the new component, remove the heat from the solder. Heat the remaining pad with the soldering iron and apply solder until it wicks to the component. If necessary, touch up the first side. All solder joints should be smooth and shiny.

3. **To replace a chip component using hot air**, select the hot-air hand piece and reflow the solder on the solder pads to smooth it. Apply a drop of solder paste flux to each pad. Using a pair of tweezers, position the new component in place. Position the hot-air hand piece approximately 1/8" above the component and begin applying heat. Once the solder wicks to the component, remove the heat and inspect the repair. All joints should be smooth and shiny.

Over-Molded Pad-Array Carrier (OMPAC)

⚠ CAUTION

All pad-array carriers in these radios, except for the IF IC (U3), are OMPAC. All OMPACs must be kept in a sealed bag with dessicant in the bag (in a “dry box”) as supplied by the Motorola Parts Department prior to use. If the OMPAC is ambient for an unknown amount of time or for more than 96 hours, then it must be baked for at least eight hours at 260 degrees F. (125 degrees C.)

⚠ CAUTION

If neighboring OMPAC components are heated above 365 degrees F. (185 degrees C.), they will suffer die-bond delamination and possible “popcorn” failure.

During all repair procedures, heating neighboring components can be minimized by doing the following:

- using upper heat only
- using the correct size heat-focus head, approximately the same size as the carrier being replaced
- keeping the heat focus head approximately 1/8" (0.3cm) above the printed circuit board when removing or replacing the device.

1. **To remove an OMPAC**, select the R-1070 Air-Flow Station and the appropriate heat- focus head (approximately the same size as the OMPAC. Attach the heat-focus head to the chimney heater. Adjust the temperature control to approximately 415 degrees F. (215 degrees C.) 445 degrees F. (230 degrees C.) maximum. Adjust the airflow slightly above the minimum setting. Apply the solder paste flux around the edge of the OMPAC. Place the circuit board in the R-1070’s circuit board holder, and position the OMPAC under the heat-focus head. Lower the vacuum tip and attach it to the OMPAC by turning on the vacuum pump. Lower the heat-focus head until it is approximately 1/8” (0.3cm) above the carrier. Turn on the heater and wait until the OMPAC lifts off the circuit board. Once the part is off, grab it with a pair of tweezers and turn off the vacuum pump. Remove the circuit board from the R-1070’s circuit board holder.

2. **To replace an OMPAC**, the solder pads on the board must first be cleaned of all solder to ensure alignment of the new chip carrier. Prepare the sight by using solder wick and a soldering iron to remove all solder from the solder pads on the circuit board. If a power desoldering tool is available, it can be used instead of the solder wick. Clean the solder pads with alcohol and a small brush. Dry and inspect. Ensure that all solder is removed.

   Once the preparation is complete, place the circuit board back in the R-1070’s circuit board holder. Add solder paste flux in the trench of the flux block and spread it using a one-inch putty knife. Flux the OMPAC by placing it in the trench of the flux block. Once the flux is applied, place the OMPAC on the circuit board, making certain that it is oriented correctly on the board. Position the heat-focus head over the OMPAC and lower it to approximately 1/8" (0.3cm) over the carrier. Using the same heat and airflow setting used to remove the OMPAC, turn on the heater and wait for the carrier to reflow (heating and reflow should take longer than 60 seconds).

   Once the carrier reflows, raise the heat-focus head and wait approximately one minute for the part to cool. Remove the circuit board and inspect the repair. No cleaning should be necessary.

Shields

Removing and replacing the shields will be done with the R-1070, using the same heat and airflow profile used to remove and replace OMPAC components.

Place the circuit board in the R-1070’s holder. Select the proper heat focus head and attach it to the heater chimney. Add solder paste flux around the base of the shield. Position the shield under the heat-focus head. Lower the vacuum tip and attach it to the shield by turning on the vacuum pump. Lower the focus head until it is approximately 1/8" (0.3cm) above the shield. Turn on the heater and wait until the shield lifts off the circuit board. Once the shield is off, turn off the heat, grab the part with a pair of tweezers, and turn off the vacuum pump. Remove the circuit board from the R-1070’s circuit board holder.

To replace the shield, add solder to the shield if necessary, using a micro-tipped soldering iron. Next, rub the soldering iron tip along the edge of the shield to smooth out any excess solder. Use solder wick and a soldering iron to remove excess solder from the solder pads on the circuit board. Place the circuit board back in the R1070’s circuit board holder. Place the shield on the circuit board using a pair of tweezers.

Position the heat-focus head over the shield and lower it to approximately 1/8" above the shield. Turn on the heater and wait for the solder to reflow.

Once complete, turn off the heat, raise the heat-focus head, and wait approximately one minute for the part to cool. Remove the circuit board and inspect the repair. No cleaning should be necessary.

Section 9
Theory of Operation
(Basic Functional Description)

Introduction

Purpose

This section provides an explanation of the VISAR series portable radio's operational theory, troubleshooting, and other useful information about VISAR not found in other Motorola publications.

In this section, a description of the basic operation of the radio is followed by a detailed representation of some selected circuits. All applicable frequency bands are covered.

Please note that, in certain instances, module references and their pin numbers are written in this fashion: module reference-pin number; for example, U701 pin J4 might be written as U701-J4.

Printed Circuit Boards and Flexible Circuits

Chip carriers mounted on two rigid, printed circuit boards (PC boards)—the transceiver board and the controller board—contain most of the radio's circuitry. All discrete wiring has been replaced with three flexible circuits: the controls flex, the display flex assembly, and the interconnect flex. The controls flex interconnects the top and side controls with the controller board. The display flex routes signals between the controller and the display. The interconnect flex sends information between the transceiver and controller boards.

Radio Power

B+ Routing and DC Voltage Distribution (for a VHF, UHF, 800, or 900MHz Transceiver and a Controller)

A 7.5-volt battery (BATT 7.5V) supplies power for the radio directly to the transceiver board as B+. The B+ voltage is fused, routed through the interconnect flex as Raw B+, and applied through the controller board to the controls flex. In the controls flex, B+ is channeled to the on / off / volume control. When the radio is turned on, the voltage sources required to operate various stages of the radio, including switched B+ (SB+), are distributed as shown in Figure 9-1.

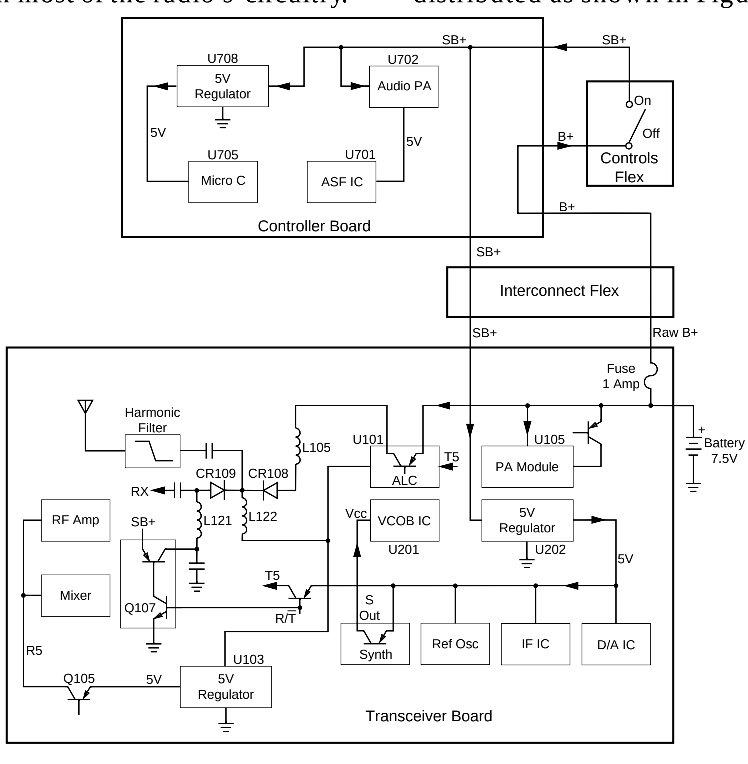


Figure 9-1. DC Power Distribution Block Diagram

BATT B+ directly drives the power amplifier (PA) module, U105, and the automatic level control (ALC) integrated circuit (IC), U101, on the transceiver board. Other sections of the transceiver board are powered-up through the switched B+. Two 5-volt regulators are used on the transceiver board. One 5V regulator (U202) is used to supply those circuits which require constant voltages, such as the reference oscillator, synthesizer IC, intermediate frequency (IF) IC, and digital-to-analog (D / A) IC. (The voltage-control oscillator [VCO] buffer obtains its voltage [Vcc] from the S Out line of the synthesizer.) The other 5V regulator (U103), supplies 5V to the receiver RF AMP IC and Mixer IC during the receive mode, and to the ALC and other transmitter circuitry during the transmit mode.

The controller board obtains its voltage source from switched B+. Two 5-volt regulators are used on the controller board. One 5V regulator (U708) is used to supply 5V to the microcontroller. The SB+ is also connected to the AUDIO PA. The other 5V regulator is in the AUDIO PA (U702); it supplies 5V (Vcc) to the audio signalling filter (ASF) IC.

VHF and UHF Transceiver Boards

Frequency Generation Unit

The frequency generation unit (FGU) on the transceiver board consists of three major sections:

1. the high stability reference oscillator (U203),
2. the fractional-N synthesizer (U204), and
3. the VCO buffer IC (U201).

The VCO provides both the carrier frequency for the transmitter (TX OUT) and the local oscillator (LO) injection signal for the receiver mixer buffer (RX OUT).

The RX VCO uses an external active device, whereas the TX VCO uses the internal device of the VCO buffer IC. The phase-locked loop (PLL) circuit is provided by the fractional-N synthesizer IC.

The output of the VCO is amplified by the prescaler buffer, routed through a low-pass filter, and applied to the prescaler divider of the synthesizer. The divide ratios are determined from information stored in memory which was bussed to the synthesizer from the microcontroller on the controller board. The microcontroller extracts data for the division ratio as determined by the channel selector (the radio up or down buttons). The resulting VCO buffer signal is applied to a comparator in the synthesizer. The synthesizer comparator also receives a reference frequency by way of a reference divider input from the 16.8MHz temperature-compensated reference oscillator. If the two frequencies differ, the synthesizer generates a control (error) voltage which causes the VCO to change frequency.

Modulation of the carrier is achieved by using a 2-port modulation technique. The deviation of the low frequency tone is obtained by injecting the signal into an analog / digital circuit in the synthesizer. The resulting digitized signal is then modulated by the fractional N-divider; this gives the required deviation. The deviation of the high frequency tone is achieved by modulating the modulation varactor on the VCO. In order to cover a very wide bandwidth, the VCO control voltage is stepped-up by using a positive and negative multiplier circuit. A 13-volt supply powers the phase detector circuitry. The VCO signal is amplified by the integrated buffer amplifier of the VCO buffer. The two output signals (receiver first LO injection and transmitter carrier frequency) are filtered and then routed to the mixer / buffer (U2) and the RF PA (U105), respectively. (See Figure 9-2)

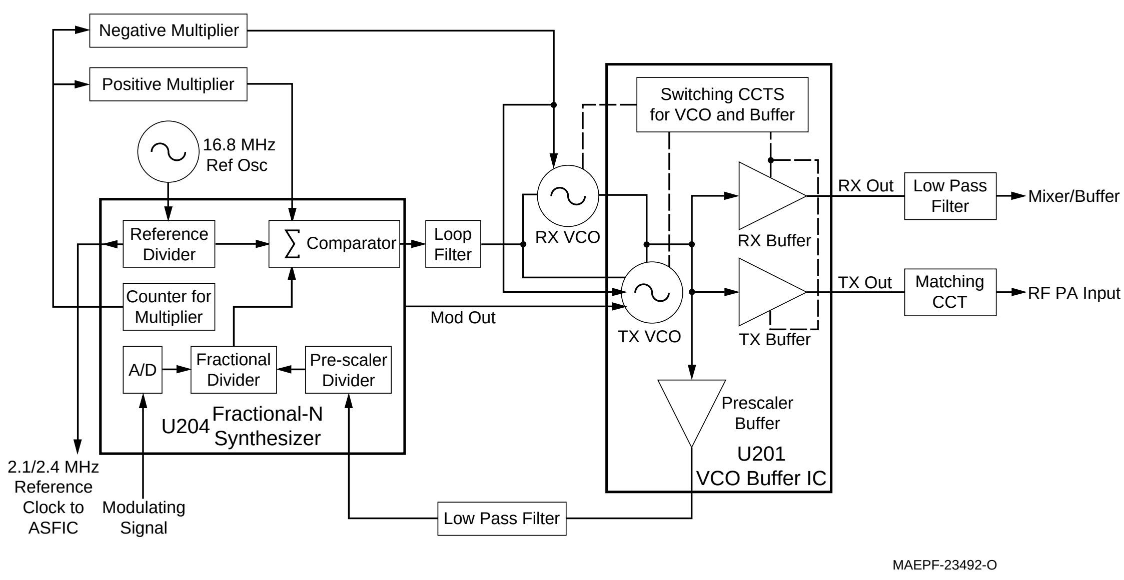


Figure 9-2. VHF, UHF Frequency Generation Unit (FGU) Circuits

Antenna Switch

When the radio is transmitting, the antenna switch, which consists of a current device, routes radio frequency (RF) to the antenna. When the radio is receiving, the device channels RF from the antenna to the receiver front end.

Receiver Front End

The RF signal from the antenna is coupled to the first bandpass filter through the antenna switching device. The output of the bandpass filter is then applied to a wideband RF amplifier IC (RF AMP). The bandpass filter is electronically tuned by the microcontroller-driven D / A IC. Wideband operation is achieved by re-tuning the bandpass filter across the band. After amplification, a second fixed-tuned filter improves the spurious rejection on the RF signal.

The filtered RF signal is then channeled to the RF input of the broadband mixer. An injection signal (first LO), from the FGU, is applied to the second input of the mixer stage. The resulting frequency, 44.85MHz for VHF or 73.35MHz for UHF, becomes the first IF frequency. The first IF frequency is passed through the 2-pole crystal filter to remove unwanted mixer products; it is then routed to the IF IC. (See Figure 9-3)

Receiver Back End

In the IF IC, the first IF frequency is down-converted, amplified, filtered, and demodulated to produce the recovered audio. The IF IC is electronically programmable; the amount of filtering is dependent upon the radio channel spacing, which is governed by the microcontroller (U705). Additional filtering, once provided externally by a conventional ceramic filter, is now done by filters inside the IF IC. The IF IC uses a direct conversion process; the second LO frequency is very close to the first IF frequency. A phased-locked operation is produced: the IF IC controls the second LO and causes the VCO to track the first IF frequency. The IC also provides a received signal-strength indicator (RSSI) and squelch output for use in other parts of the radio. (See Figure 9-3)

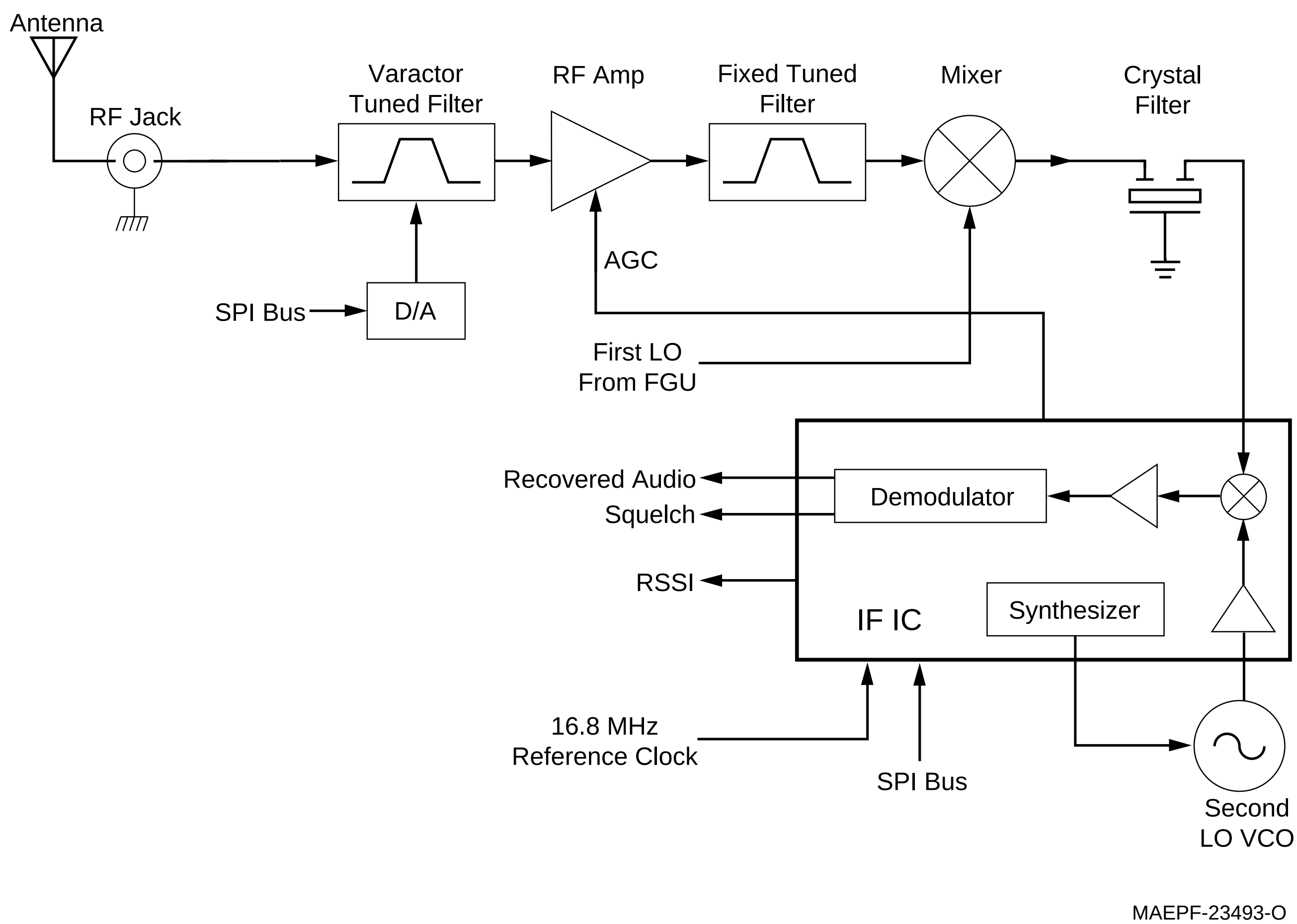


Figure 9-3. VHF, UHF Receiver Block Diagram

Transmitter

The transmitter consists of the following stages:

- Harmonic Filter
- RF Power Amplifier (PA)
- ALC IC, which controls the power output

Harmonics of the carrier frequency are generated by the PA module and antenna switch. The harmonic filter circuit attenuates the unwanted signals.

The RF PA module is a multi-stage amplifier; it has the required gain to produce an output level of several watts. Some harmonic filtering is accomplished in the RF PA.

Power control is achieved by using the coupler detector to feed back part of the PA output to the ALC circuit. This ALC circuit appropriately increases or decreases the overall PA gain. Another function of the coupler detector is to provide a signal when the voltage standing wave ratio (VSWR) exceeds the threshold level.This signal, combined with the forward detected power, is used to reduce the PA output power. This protects the power amplifier under high VSWR conditions. (See Figure 9-4)

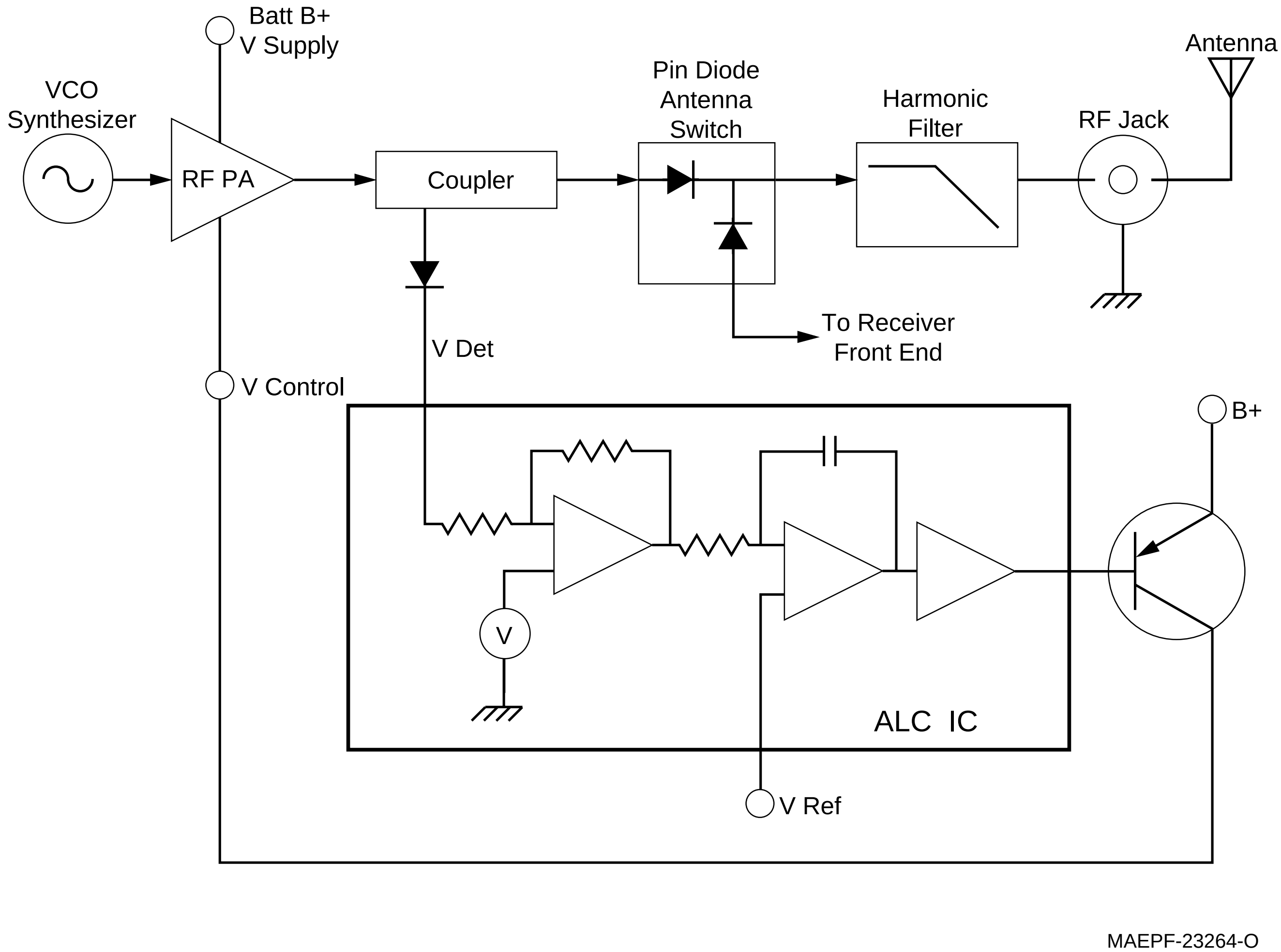


Figure 9-4. VHF, UHF Receiver Block Diagram

800 and 900MHz Transceiver Board

Frequency Generation Unit

The frequency generation unit (FGU) consists of the following major sections: the high stability reference oscillator (U203), fractional-N synthesizer (U204), VCO buffer IC (U201), and VCO (U205). The VCO provides the carrier frequency for the transmitter (TX OUT), and provides the local oscillator (LO) injection signal for the receiver mixer buffer (RX OUT). The phase-locked loop (PLL) circuit is provided by the fractional-N synthesizer IC.

The output of the VCO is amplified by the prescaler buffer, routed through a low-pass filter, and applied to the prescaler dividers of the synthesizer. The divide ratios are determined from information stored in memory and bussed to the synthesizer by way of the microcontroller. The microcontroller extracts data for the division ratio as determined by the channel-select switch. The resulting VCO buffer signal is applied to a comparator in the synthesizer. The synthesizer comparator also receives a reference frequency by way of a reference divider input from the 16.8MHz temperature-compensated reference oscillator. If the two frequencies differ, the synthesizer generates a control (error) voltage causing the VCO to change frequency.

Modulation of the carrier is achieved by using a 2-port modulation technique. The deviation of the low frequency tone, such as DPL / TPL, is achieved by injecting the signal into an analog / digital circuit in the synthesizer. The resulting digitized signal is then modulated by the fractional N-divider; this generates the required deviation. The deviation of the high frequency tone is achieved by modulating the modulation varactor on the VCO. In order to cover a very wide bandwidth, the VCO control voltage is stepped up by using a positive multiplier circuit. A 13-volt supply powers the phase detector circuitry. The VCO signal is amplified by the integrated buffer amplifier of the VCO buffer. The two output signals (receiver first LO injection and transmitter carrier frequency) are filtered and channeled to the mixer / buffer (U2) and the RF PA (U105), respectively. (See Figure 9-5)

Antenna Switch

The function of the antenna switch is to route the transmitter power to the antenna during transmission, or to route the RF from the antenna to the receiver front end during receiving.

Receiver Front End

The RF signal from the antenna is coupled to the first bandpass filter through the antenna switch. The output of the bandpass filter is then applied to a wideband RF amplifier IC (RF AMP). The bandpass filter is a wideband stripline filter pre-tuned for the frequency band. After amplification, the RF signal is further filtered by a second fixed-tuned stripline filter to improve the spurious rejection.

The filtered RF signal is then applied to the RF input of a broadband mixer IC (U2). An injection signal (FIRST LO) supplied by the FGU, is applied to the second input of the mixer stage. The resulting difference in frequency of 73.35MHz becomes the first IF frequency. The first IF frequency is then filtered by a 2-pole crystal filter (FL1) to remove unwanted mixer products, and then routed to the IF IC (U3). (See Figure 9-5)

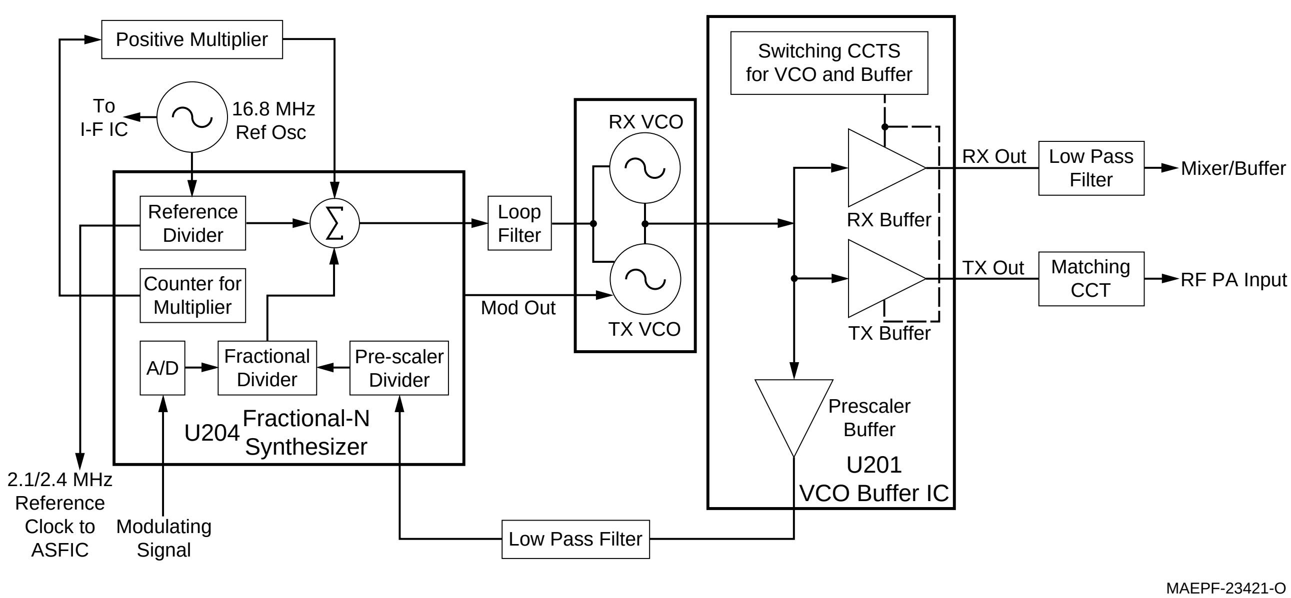


Figure 9-5. 800 and 900MHz Frequency Generation Unit (FGU) Circuits

Receiver Back End

In the IF IC, the first IF frequency is down-converted, amplified, filtered, and demodulated to produce the recovered audio. The IF IC is electronically programmable, and the amount of filtering, which depends upon the radio channel spacing, is controlled by the microcontroller. Filtering is accomplished by internal filters in the IF IC. The IF IC uses a type of direct conversion process, whereby the second LO frequency is very close to the first IF frequency. The IF IC controls the second LO VCO and causes the VCO to track the first IF frequency; this produces a phase-locked operation. The IF IC also provides a recovered signal-strength indicator (RSSI), and squelch output, for use in other parts of the radio. (See Figure 9-6)

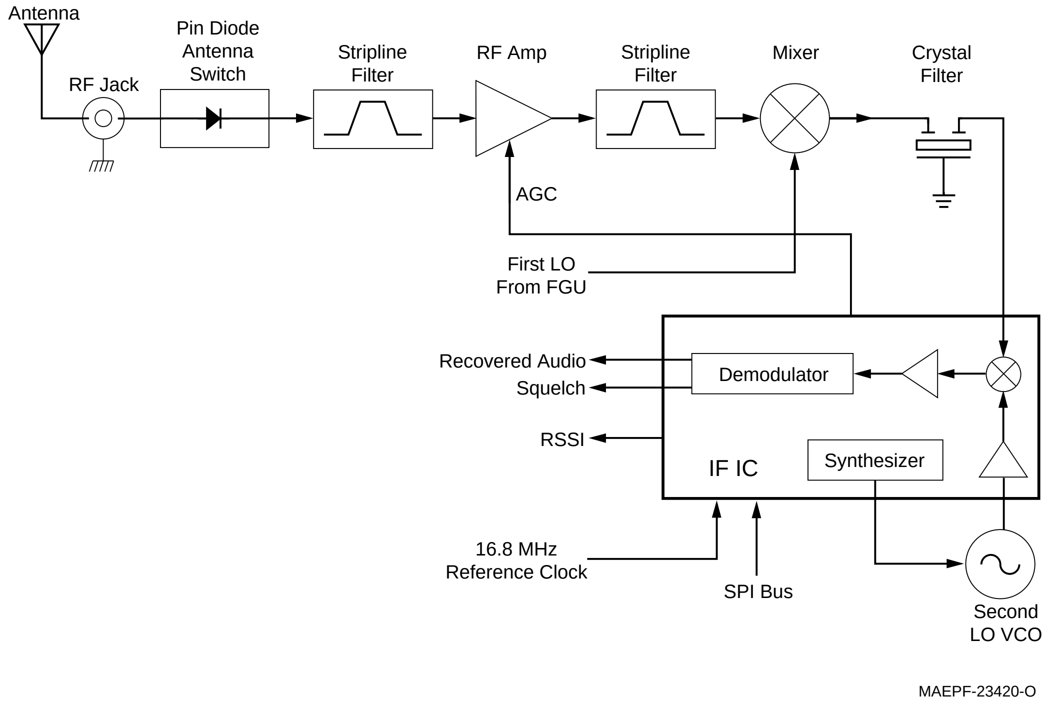


Figure 9-6. 800 and 900MHz Receiver Block Diagram

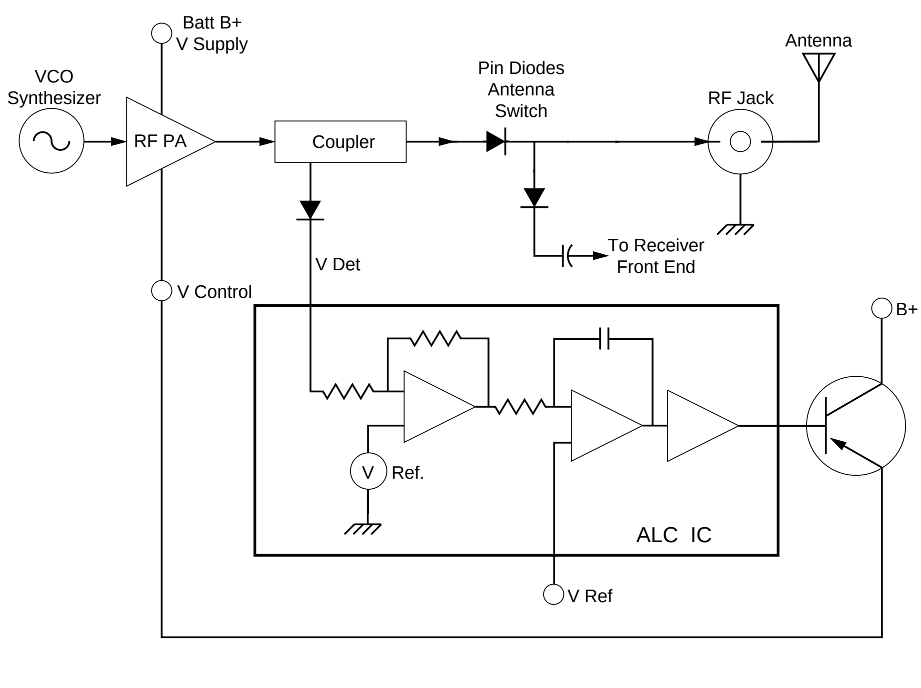


Figure 9-7. 800 and 900MHz Transmitter Block Diagram

Transmitter

The transmitter consists of the following stages:

- Low-pass antenna matching circuit
- RF Power Amplifier
- ALC IC and coupler, for power output control

The low-pass antenna matching circuit attenuates RF PA harmonics and provides the optimum phase load to the RF PA. The RF PA module is a multi-stage amplifier; it has the required gain to produce an output level of several watts. Some harmonic filtering is also accomplished in the RF PA.

Power control is achieved by using the coupler detector to return a portion of the PA output to the ALC circuit. This ALC circuit appropriately increases or decreases the overall PA gain. Another function of the detector is to provide a signal when the VSWR exceeds the threshold level. This signal, combined with the forward detected power, is used to reduce the PA output power; this protects the PA under high VSWR conditions. (See Figure 9-7)

Controller Board

General

The controller board is the central interface between the various subsystems of the radio. It is separated into digital and audio architecture. The digital portion consists of a special Motorola microcontroller. The audio power amplifier (AUDIO PA) and audio / signalling / filter IC (ASF IC) form the backbone of the audio / signalling architecture.

Digital Architecture

The microcontroller consists of 640 bytes of EEPROM, 1k bytes of RAM, and 32k bytes of ROM. The microcontroller executes the radio software and monitors the activity of all user interfaces. The communication busses enable the microcontroller to have the responsibility of programming of all applicable ICs in the radio, including those on the transceiver board. This programming instructs the ICs to perform a variety of functions, from channel scan to frequency selection. A discrete, 5-volt regulator powers the digital circuitry and helps isolate the digital signals from the audio signals in nearby circuits. (See Figure 9-8)

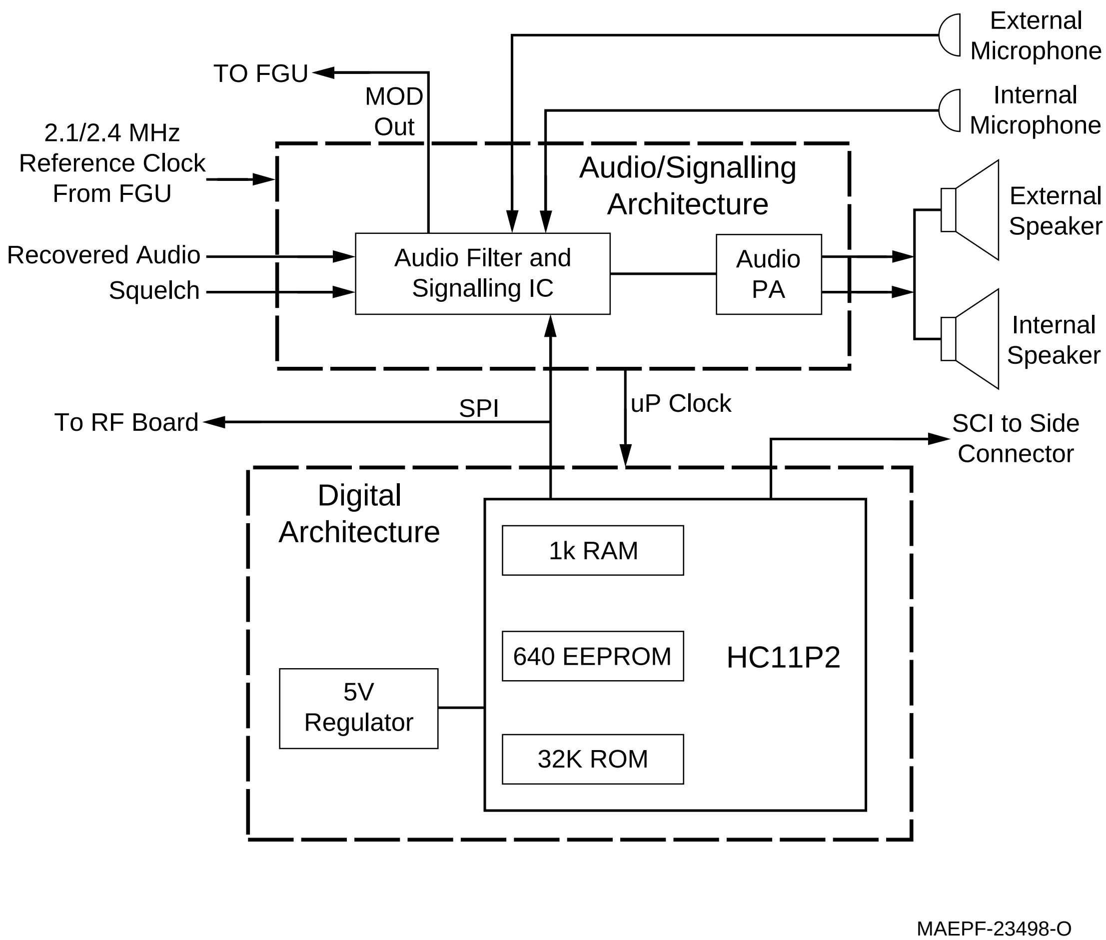


Figure 9-8. Controller Block Diagram

Audio Signalling Architecture

A Motorola custom IC (ASF) provides the transmit audio, receive audio, and signal processing. The ASF IC is programmable by the microcontroller by way of the serial peripheral interface (SPI). It provides filtering on both transmit and receive audio; it also provides PL, DPL, and MDC encoding and decoding.

In the transmit mode, the ASF IC amplifies, shapes, limits, and filters the outgoing signal. The processed signal is sent to the transceiver board's FGU.

In the receive mode, the demodulated signal from the receiver back end is amplified, filtered, and routed to the AUDIO PA for amplification. The ASF IC provides pre-emphasis and de-emphasis as well as squelch. Based on a reference signal from the transceiver board, the ASF IC provides the microcontroller with a clock signal.

Received audio signal amplification is achieved by the AUDIO PA IC. This IC's output drives the radio's internal speaker. It can also drive an external speaker using the external side connector or audio jack. The audio section has its own isolated 5V regulator on the AUDIO PA to further isolate audio signals from the digital signals, and to minimize the audio's unwanted effects.

Section 10
Theory of Operation
(Detailed Functional Description)

Introduction

A more detailed description of the radio and some of the special circuitry is given in this section of the manual. For a better understanding of the circuits' descriptions, and to aid in following the text, refer to the applicable VISAR schematic diagram(s).

Radio Power

General

As previously described in the "Theory of Operation (Basic Functional Description) Radio Power" paragraph, power is distributed to two general combinations of transmitters and controllers:

1. VHF or UHF transceivers with controller
2. 800MHz transceiver with controller

The next paragraph begins the detailed theory of operation of the VHF, UHF, or 800MHz transceivers and the controller.

B+ Routing and DC Voltage Distribution (for a VHF, UHF, 800, or 900MHz Transceiver and a Controller)

Raw B+ (7.5V) from the battery (Batt B+) enters the radio on the transceiver board through a 3-contact spring pin arrangement (P404) as B+. From there it is routed directly to the RF PA Module and ALC IC (U101) pin 20. Battery B+ is fused, and then sent through the interconnect flex (J301, pins 1 and 20) to the controller board (J704, pins 1 and 20). The B+ supply is routed through the controller board to the on / off / volume control (S403) on the controls flex at jack J703, pin 16. With the mechanical on / off switch (S403) placed in the "on" position, switched B+ (SB+) is channeled from the controls flex at connector plug P703, pin 12 and applied to the controller at connector jack J703, pin12. This signal is also fed to a resistive divider (R725, R726) so that the microcontroller (U705) can monitor the battery voltage.

The SB+ voltage powers the audio PA (U702) and its internal 5V regulator booster transistor (Q701). It also powers a discrete 5V regulator (U708). Regulated 5-volts from module U708 powers the microcontroller (U705) and other digital circuitry. The ASF IC (U701) obtains its 5V (Vcc) from the AUDIO PA internal 5V regulator through a booster transistor (Q701).

The switched B+ voltage supplies power to circuits on the transceiver board. This voltage is applied to the 5-volt regulator (U202) through the decoupling component (C125); this produces a stable 5.0 volt output. Raw B+ (7.5V), which is connected to the ALC IC (U101), is switched through the output (CATH1) to another 5-volt regulator (U103).

Regulator U202 supplies those circuits which need to remain on at all times, such as the reference oscillator (U203), fractional-N-synthesizer (U204), D / A IC (U102), and the IF module (U3). The D / A IC controls the dc switching of the transceiver board. The SC1 signal at U102 pin 12 controls transistors Q107, Q104, and the transmit 5 volts (TX 5V). The SC3 signal at U102 pin 14 controls transistor Q105 and the receive 5 volts (RX 5V). A voltage on the synthesizer SOUT line at U204 pin 19 supplies power (Vcc) to the VCO buffer at U201 pin 3.

During the receive mode, regulator U103 (through switching transistor Q105) supplies regulated 5V (R5) to the receiver front end. In the battery-saver mode, R5 can be switched on and off by controlling pin 1 of transistor Q105. Module U103 is not used during the transmit mode. During the transmit mode, transmit 5 volts (T5) for the ALC IC, and the other TX circuitry, is obtained from U202 through switching transistor Q104.

The low-battery detect circuit on the controller board produces an audio alert when the radio's battery needs recharging. The microcontroller's on-chip, 8-bit, 8-channel, A / D converter (U705 pins PE0 through PE7) makes this possible. The 7.5V (SB+) is divided down to a nominal 3.92V by resistors R725 and R726, and fed to port PE4 of U705. This voltage is converted by the A / D converter to a digital format. The microcontroller compares this voltage to a preset low-battery trip threshold, which corresponds to a battery voltage of 7.04V in standby or 6.2V in transmit. If the measured voltage is lower than either threshold, and the low-battery alert tone is enabled, the user is warned that approximately 20 minutes of usable battery power remains.

VHF and UHF Transceiver Boards

Frequency Generation Unit (FGU)

The frequency generation unit (FGU) consists of three major sections: the high-stability reference oscillator (U203), the fractional-N synthesizer (U204) and the VCO buffer (U201). A 5V regulator (U202), supplies power to the FGU. The synthesizer receives the 5V REG at U204 pin 41, and applies it to a filtering circuit within the module and capacitor C253. The well-filtered 5-volt output at U204 pin 19 is distributed to the TX VCO, RX VCO, and the VCO buffer IC. The mixer LO injection signal and transmit frequency are generated by the RX VCO and TX VCO respectively. The RX VCO uses an external active device (Q202), whereas the TX VCO active device is a transistor inside the VCO buffer. The base and emitter connections of this internal transistor are pins 11 and 12 of U201.

The RX VCO is a Colpitts-type oscillator, with capacitors C235 and C236 providing feedback. The RX VCO transistor (Q202) is turned on when pin 7 of U201 switches from high to low. The RX VCO signal is received by the VCO buffer at U201 pin 9, where it is amplified by a buffer inside the IC. The amplified signal at pin 2 is routed through a low-pass filter and injected as the first LO signal into the mixer (U2 pin 8). In the VCO buffer, the RX VCO signal (or the TX VCO signal during transmit) is also routed to an internal prescaler buffer. The buffered output at U201 pin 16 is applied to a low-pass filter (L205 and associated capacitors). After filtering, the signal is routed to a prescaler divider in the synthesizer at U204 pin 21.

The divide ratios for the prescaler circuits are determined from information stored in a codeplug, which is part of the microcontroller (U705). The microcontroller extracts data for the division ratio, as determined by the up or down channel selector buttons, and busses the signal to a comparator in the synthesizer. A 16.8MHz reference oscillator, U203, applies the 16.8MHz signal to the synthesizer at U204 pin 14. The oscillator signal is divided into one of three pre-determined frequencies. A time-based algorithm is used to generate the fractional-N ratio.

If the two frequencies in the synthesizer's comparator differ, a control (error) voltage is produced. The phase detector error voltage (V control) at pins 31 and 33 of U204 is applied to the loop filter, consisting of resistors R211, R212, and R213, and capacitors C244, C246, C247 and C275. The filtered voltage alters the VCO frequency until the correct frequency is synthesized. The phase detector gain is set by components connected to U204 pins 28 and 29.

In the TX mode, U201 pin 7 goes high and U201 pin 14 goes low; this turns off transistor Q202 and turns on the internal TX VCO transistor in U204. The TX VCO feedback capacitors are C219 and C220. Varactor diode CR203 sets the TX frequency, while varactor CR202 is the TX modulation varactor. The modulation of the carrier is achieved by using a 2-port modulation technique. The modulation of low frequency tones such as DPL / TPL is achieved by injecting the tones into the A / D section of the fractional-N synthesizer. The digitized signal is modulated by the fractional-N divider; this generates the required deviation. Modulation of the high frequency audio signals is achieved by modulating the varactor (CR202) through a frequency-compensation network. Resistors R207 and R208 form a potential divider for the higher frequency audio signals.

In order to cover the very wide bandwidths, positive and negative V-control voltages are used. High control voltages are achieved using positive and negative multipliers. The positive voltage multiplier circuit consists of components CR204, C256, C257, and reservoir capacitor C258.The negative multiplier circuit consists of components CR205, CR206, C266, C267, and reservoir capacitor C259 in VHF radios, or C284 in UHF radios. Out-of-phase clocks for the positive multiplier appear at U204 pins 9 and 10. Out-of-phase clocks for the negative multiplier appear at U204 pins 7 and 8, and only when the negative V-control is required (that is, when the VCO frequency exceeds the crossover frequency). When the negative V-control is not required, transistor Q201 is turned on, and capacitor C284 in UHF, or C259 in VHF, discharges. The 13V supply generated by the positive multiplier is used to power-up the phase detector circuitry. The negative V-control is applied to the anodes of the VCO varactors.

The TX VCO signal is amplified by an internal buffer in U201. The signal is then routed through a low pass filter comprised of L224, C201, and C292, and channeled to the TX PA module, U105 pin 1. The TX and RX VCOs and buffers are activated using a control signal from U204 pin 38.

The reference oscillator supplies a 16.8MHz clock to the synthesizer, where it is divided down to either a 2.1MHz or a 2.4MHz clock. This divided-down clock is fed to the controller board ASF IC (U701); there, it is further processed for internal use. Module U701 also uses this signal to synthesize the microcontroller clock. The controller will program the synthesizer to provide 2.1MHz or 2.4MHz, as required.

Antenna Switch

The switch is a current device. A pair of diodes (CR108 and CR109) electronically steer RF between the receiver and the transmitter. In the transmit mode, RF is routed through the transmit-switching diode, CR108, and sent to the antenna. In the receive mode, RF is received from the antenna, routed through receive-switching diode, CR109, and applied to the RF amplifier, U1. In transmit, bias current, sourced from U101 pin 21, is channeled through L105, U104, CR108, and L122. Sinking of the bias current is done through the transmit ALC module, U101 pin 19. In the receive mode, bias current, sourced from SB+, is routed through Q107 (pin 3 to pin 2), L131 (VHF) or L123 (UHF), L121, CR109, and L122. Sinking of the bias current is done through the 5-volt regulator, U103 pin 3.

Receiver Front End

The RF signal is received by the antenna and applied to a low-pass filter. For VHF, the low-pass filter is comprised of L126, L127, L128, C130, C149, C150, and C151. For UHF, the filter consists of L126, L127, L128, C149, C150, and C151. The filtered RF signal is passed through the antenna switch (CR109) and applied to a bandpass filter. For VHF, the bandpass filter is comprised of L11, L30 thru L35, CR6 thru CR9, C1, C2, and C3. For UHF, the filter consists of L30, L31, L32, L34, L35, CR6 thru CR9, C1, C2, and C3. The bandpass filter is tuned by applying a control voltage to the varactor diodes in the filter. In VHF, the diodes are CR1 through CR9; in UHF, they are CR6 through CR9.

The bandpass filter is electronically tuned by the D / A IC (U102), which is controlled by the microcontroller. The D / A output range is extended through the use of a current mirror: transistor Q108 and associated resistors R115 and R116. When Q108 is turned on via R115, the D / A output is reduced due to the voltage drop across R116. Depending on the carrier frequency, the microcontroller will turn Q108 on or off. Wideband operation of the filter is achieved by returning the bandpass filter across the band.

The output of the bandpass filter is transferred to the wideband GaAs RF amplifier IC, U1 (RF AMP). Automatic gain control (AGC) is applied to the RF amplifier through an AGC network consisting of pin diode CR11, resistor R72 (VHF) or R52 (UHF), and inductor L32 (VHF) or L16 (UHF). The AGC control voltage is derived from pin 4 of the IF IC, U3. Bypassing is provided by capacitors C70 (VHF) and C59 (UHF), while temperature compensation is provided by the Schottky diode CR12 and resistor R70 (VHF), or R51 (UHF). When a strong signal is received, the voltage at U3 pin 4 drops, causing current to flow from the receive 5-volt line (R5) through the pin diode (CR11). When this happens, the RF signal is shunted to ground by way of capacitor C16; this reduces the amplitude of the RF signal applied to the 1st mixer. When the received RF signal is very weak, the voltage at U3 pin 4 rises and no current flows through CR11. The RF amplifier will then be at maximum gain. After being amplified by the RF AMP, the RF signal is further filtered by a second broad-band, fixed-tuned, bandpass filter, consisting of C6, C7, C8, C80, C86, C87, C88, C97, C99, L3, L4, L5, and L30 for VHF; for UHF, the filter is comprised of C4 thru C7, C88 thru C94, C99, and L11 thru L15.

By way of a broadband 50-ohm transformer, T1, the filtered RF signal is routed to the input of a broadband mixer / buffer (U2). Mixer U2 uses GaAs FETs, in a double-balanced Gilbert Cell configuration. The RF signal is applied to the mixer at U2 pins 1 and 15. An injection signal (1st LO) of about -10dBm, supplied by the FGU, is applied to U2 pin 8. Mixing of the RF and the 1st LO results in an output signal which is the first IF frequency. The first IF frequency of the VHF band is 44.85MHz. Of the UHF band, the first IF frequency is 73.35MHz. The 1st LO signal for VHF is 44.85MHz higher than the carrier frequency, while for the UHF it is 73.35MHz lower than the carrier frequency. The 1st IF signal output, at U2 pins 4 and 6, is routed through transformer T2 and impedance-matching components, and applied to a 2-pole crystal filter (FL1). FL1 is the final stage of the receiver front end. The 2-pole crystal filter removes unwanted mixer products, such as the filtered IF signals being routed to the IF module, U3. Impedance matching between the output of the transformer (T2) and the input of the filter (FL1) is accomplished by capacitors C35 and C36 and inductor L20.

Receiver Back End

The output of crystal filter FL1 is matched to the input of IF buffer amplifier transistor Q4 by components L22 and C38. Transistor Q4 is biased by the voltage level on U3 pin 2. The IF frequency on the collector of Q4 is applied to U3 pin 2, where it is down-converted, amplified, filtered, and demodulated, to produce the recovered audio at U3 pin 28. This IF IC is electronically programmable, and the amount of filtering (which is dependent on the radio channel spacing) is controlled by the microcontroller. Additional filtering, once externally provided by conventional ceramic filters, is replaced by internal filters in the IF module. The IF IC uses a type of direct conversion process, whereby the second LO frequency is very close to the first IF frequency. The IF IC synthesizes the second LO and phase-locks the VCO to track the first IF frequency.

In the absence of an IF signal, the VCO will “search” for a frequency, or its frequency will vary close to the IF frequency. When an IF signal is received, the VCO will lock onto the IF signal. The 2nd LO / VCO is a Colpitts oscillator built around transistor Q1. The VCO has a varactor diode, CR5, to adjust the VCO frequency. The control signal for the varactor is derived from a loop filter consisting of C52, C53, and R16.

The IF IC (U3) performs several other functions. It provides a received signal-strength indicator (RSSI) and a squelch output. The RSSI is a dc voltage monitored by the microcontroller, and used as a peak indicator during the bench tuning of the receiver front-end varactor filter. The RSSI dc voltage is sent from U3 pin 9 to connector jack J301 pin 11; there it is routed through the jumper flex (P301 pin 11 to J704 pin 11) and applied to the controller board. In the controller board, the RSSI is channeled through the ASF IC (U701 pad G8 to U701 pad B2), and applied to the controls flex at J703 pin 11. By way of the controls flex, the RSSI voltage reaches the universal connector at P403 pin 9 as AUX TX / RSSI. The squelch output of U3, on pin 29, is a high-frequency audio signal. The squelch signal is routed to shaping and detection circuits within U701 on the controller board for use in other parts of the radio. The IF module (U3) also monitors the strength of the received signal to provide an AGC voltage at pin 4; from there it is fed to the RF amplifier AGC circuit. Inductor L23 and capacitor C70 prevent any IF signal from leaking back to the front-end circuits.

Transmitter

The transmitter consists of three major sections:

- Harmonic Filter
- RF Power Amplifier Module
- ALC Circuits

Harmonic Filter

RF from the Power Amplifier (PA) module, U105 is routed through the coupler (U104), passed through the transmit antenna switch (CR108), and applied to an harmonic filtering network. The harmonic filtering circuit for VHF models is comprised of L126, L127, L128, C149, C150, and C151. For UHF models, the filtering circuit consists of L126, L127, L128, C129, C130, C149, C150, and C151.

RF Power Amplifier Module

The RF power amplifier module (U105) is a wide-band, multi-stage amplifier. Three stages are provided for the VHF models and four stages for the UHF models. Nominal input and output impedance of U105 is 50 ohms. The dc bias for U105 is on pins 2, 4, and 5. In the transmit mode, the voltage on U105 pins 2 and 4 (close to the B+ level) is obtained by way of switching transistor Q101. Transistor Q101 receives its control base signal as follows:

- the microcontroller keys the D / A IC to produce a ready signal at U102 pin 3
- the ready signal at U102 pin 3 is applied to the TX ALC IC at U101 pin 14 (5V)
- the synthesizer sends a LOC signal to the TX ALC IC (U204 pin 40 to U101 pin 16)

When the LOC signal and the ready signal are both received, the TX ALC IC (pin 13) sends a control signal to turn on transistor Q101.

ALC Circuits

Coupler module U104 samples the forward power and the reverse power of the PA output voltage. Reverse power is present when there is no 50 ohms impedance at the antenna port. Sampling is achieved by coupling some of the forward or reverse power, or both, and applying it to CR102 (VHF), or CR101 (UHF), and CR103 for rectification and summing. The resulting dc signal is then applied to U101 pin 2 (RFDET) of the TX ALC IC and used as an RF strength indicator.

The transmit ALC circuit, built around U101, is the heart of the power control loop. Circuits in the TX ALC module compare the signals at U101 pins 2 and 7. The resultant signal, C BIAS, at U101 pin 4 is applied to the base of transistor Q110. Responding to the base drive, transistor Q110 varies the dc control voltages applied to the RF PA at U105 pin 3. This controls the RF power of module U105.

Thermistor RT101 senses the temperature of the TX ALC IC. If an abnormal operating condition exists causing the PA slab temperature to rise to an unacceptable level, the thermistor forces the ALC to reduce the set power.

800 and 900MHz Transceiver Board

Frequency Synthesis

The complete synthesizer subsystem consists of the reference oscillator (U203), the voltage-controlled oscillator (VCO), U205, a buffer IC (U201), and the synthesizer (U204).

The reference oscillator contains a temperature- compensated 16.8MHz crystal. This oscillator is digitally tuned and contains a temperature-referenced 5-bit analog-to-digital (A / D) converter. The output of the oscillator (pin 10 on U203) is applied to pin 14 (XTAL1) on U204 by way of capacitor C284 and resistor R222.

Module U205 is the voltage-controlled oscillator, which is varactor-tuned; that is, as the voltage (2-11V) being applied to pins 1 and 7 of the VCO varies, so does the varactor's capacitance, thereby changing the VCO's output frequency. The 800MHz VCO is a dual-range oscillator that covers the 806-825MHz, and the 851-870MHz, frequency bands. The low-band VCO (777-825MHz) provides the first LO injection frequencies (777-797MHz) that will be 73.35MHz below the carrier frequency. In addition, when the radio is operated through a repeater, the low band VCO will generate the transmit frequencies (806-825MHz) that will be 45MHz below the receiver frequencies. The low-band VCO is selected by pulling pin 3 high and pin 8 low on U205. When radio-to-radio or talk-around operation is necessary, the high band VCO (851-870MHz) is selected. This is accomplished by pulling pin 3 low and pin 8 high on U205.

The buffer IC, U201, includes a TX, RX, and prescaler buffer. The main purpose of the buffer IC is to individually maintain a constant output and provide isolation. The TX buffer is chosen by setting pin 7 of U201 high; the RX buffer is chosen by setting pin 7 of U201 low. The prescaler buffer will always be on. In order to select the proper combination of VCO and buffer, the following conditions must be true at pin 6 of U201 (or pin 38 of U204) and pin 7 of U201 (or pin 39 of U204). For the first LO injection frequencies (A), pins 6 and 7 must both be low. For the TX repeater frequencies (B) pins 6 and 7 must both be high, and for talk-around TX frequencies (C) pin 6 must be low while pin 7 must be high.

(A) = 777-797MHz for 800MHz
(B) = 804-825MHz for 800MHz
(C) = 851-870MHz for 800MHz

The synthesizer IC, U201, consists of a prescaler, a programmable loop divider, a divider control logic, a phase detector, a charge pump, an A/D converter for low frequency digital modulation, a balance attenuator to balance the high frequency analog modulation to the low frequency digital modulation, a 13V positive-voltage multiplier, a serial interface for control, and a filter for the regulated five volts. This filtered five volts is present at pin 19 of U204, pin 9 of U205, and pins 2, 3, 4, and 15 of U201. It is also applied directly to resistors R214, R215, and R220. Additionally, the 13V, generated by the positive voltage multiplier circuitry, should be present at pin 35 of U204. The serial interface (SRL) is connected to the microcontroller by way of the data line (pin 2 of U204), clock line (pin 3 of U204), and chip enable line (pin 4 of U204).

This is a description of the entire synthesizer subsystem. The output of the VCO (pin 4 on U205) is fed into the RF input port (pin 9) of U201. In the TX mode, the RF signal will be present at pin 4 of U201. On the other hand, in the RX mode, the RF signal will be present at pin 3 of U201. The output of the prescaler buffer (pin 15 on U201) is applied to the PREIN port (pin 21) of U204. The prescaler in U204 is a dual-modulus type with selectable divider ratios. This divider ratio is controlled by the loop divider, which receives its inputs by way of the SRL. The loop divider adds or subtracts phase to the prescaler divider by changing the divide ratio by way of the modulus control line. The output of the prescaler is then applied to the loop divider. The output of the loop divider is then related to the phase detector. The loop divider's output signal is compared by the phase detector with a divided-down signal supplied from U203 at pin 14 of U204. The result of the signal comparison is a pulsed dc signal applied to the charge pump. The charge pump outputs a current present at pin 32 of U204. The loop filter (which consists of capacitors C237, C238, C246, C275, C239, and C240, and resistors R212, R211, R213, and R241) will transform this current into a voltage applied to pins 1 and 7 of U205; it alters the VCO's output frequency.

In order to modulate the PLL, the two-spot modulation method is utilized. The analog modulating signal is applied to the A/D converter, and the balance attenuator, by way of U204 pin 5. The A/D converter converts the low frequency analog modulating signal into a digital code that is applied to the loop divider; this causes the carrier to deviate. The balance attenuator is used to adjust the VCO's deviation sensitivity to high frequency modulating signals.

Antenna Switch

An electronic PIN diode switch steers RF between the receiver and transmitter. In the transmit mode, RF is routed to the anode of diode CR108. In receive mode, RF is routed to pin 1 of U4. In transmit, bias current sourced from U101 pin 21, is routed through PIN diodes CR108 and CR109, biasing them to a low impedance state. Bias current returns to ground through U101 pin 20. In receive, U101 pin 21 is pulled down to ground, and pin 20 is pulled up to B+; this reverse-biases diodes CR108 and CR109 to a high impedance.

Receiver Front End

For the purposes of this discussion, the receiver front end is defined as the circuitry from the antenna switch to the output of the IF crystal filter. The 800MHz front end is designed to convert the received RF signal to the 1st IF frequency of 73.35MHz, while at the same time providing for spurious immunity and adjacent channel selectivity. A review of the interstage components of the front end will now be presented, with emphasis on troubleshooting considerations.

The received RF signal is passed through the antenna switch input-matching components C151, L127, tank components C149 and L126 (which are anti-resonant at the radio's transmitter frequencies), and output matching components C141 and L30. Both pin diodes, CR109 and CR108, must be back-biased to properly route the received signal.

The stage following the antenna switch is a 50-ohm, inter-digitated, 3-pole, stripline preselector (U4). The preselector is positioned after the antenna switch to provide the receiver preamp some protection to strong, out-of-band signals.

After the preselector (U4), the received signal is processed through the receiver preamp, U1. The preamp is a dual-gate GaAs MESFET transistor which has been internally biased for optimum IM, NF, and gain performance. Components L32 and L34 match the input (gate 1) of the amp to the first preselector, while at the same time, connecting gate 1 to ground potential. The output (drain) of the preamp (U1) is pin 3, and it is matched to the subsequent receiver stage by way of components L10, C4 and C88. A supply voltage of 5Vdc is provided to pin 3 by way of an RF choke (L8) and a bypass (C31). The 5-volt supply is also present at pin 4, which connects to a voltage divider network that biases gate 2 (pin 5) to a predefined quiescent voltage of 1.2Vdc. Components R27 and C11 are connected to pin 5 of U1 to provide amp stability. The FET source (pin 7) is internally biased at 0.55 to 0.7Vdc for proper operation with bypass capacitors C13 and C72.

After the preselector (U4), the received signal is processed through the receiver preamp, U1. The preamp is a dual-gate GaAs MESFET transistor which has been internally biased for optimum IM, NF, and gain performance. Components L32 and L34 match the input (gate 1) of the amp to the first preselector, while at the same time, connecting gate 1 to ground potential. The output (drain) of the preamp (U1) is pin 3, and it is matched to the subsequent receiver stage by way of components L10, C4 and C88. A supply voltage of 5Vdc is provided to pin 3 by way of an RF choke (L8) and a bypass (C31). The 5-volt supply is also present at pin 4, which connects to a voltage divider network that biases gate 2 (pin 5) to a predefined quiescent voltage of 1.2Vdc. Components R27 and C11 are connected to pin 5 of U1 to provide amp stability. The FET source (pin 7) is internally biased at 0.55 to 0.7Vdc for proper operation with bypass capacitors C13 and C72.

The output of the preamp is matched to a second 3-pole preselector (U5) of the type previously discussed (U4). The subsequent stage in the receiver chain is the 1st mixer U2, which uses low-side injection to convert the RF carrier to an intermediate frequency (IF) of 73.35MHz. Since low-side injection is used, the LO frequency is offset below the RF carrier by 73.35MHz, or Flo = Frf - 73.35MHz. The mixer utilizes GaAs FETs in a double-balanced, Gilbert Cell configuration. The LO port (pin 8 of U2) incorporates an internal buffer and a phase shift network to eliminate the need for a LO transformer. The LO buffer bypass capacitors, C82, C90 and C91, are connected to pin 10 of U2, and they should exhibit a nominal dc voltage of 1.2 to 1.4Vdc. Pin 11 of U2 is LO buffer Vdd (5Vdc), with associated bypass capacitors C19 and C92 connected to the same node. An internal voltage divider network within the LO buffer is bypassed to virtual ground at pin 12 of U2 by way of bypass C84. The mixer's LO port is matched to the radio's PLL by a capacitive tap, comprised of C204 and C206. A balun transformer (T1) is used to couple the RF signal into the mixer. The primary of T1 is matched to the preceding stage by capacitor C7, with C98 providing a dc block to ground. The secondary of T1 provides a differential output, with a 180° phase differential being achieved by setting the secondary center tap to virtual ground using bypass capacitors C89, C83 and C86. The secondary of transformer T1, connected to pins 1 and 15 of the mixer IC, drives the source leg of dual FETs; the dual FETs are used to toggle the paralleled differential amplifier configuration within the Gilbert Cell. The final stage in the receiver front end is a 2-pole crystal filter, FL1. The crystal filter provides some of the receiver's adjacent channel selectivity. The receiver's back end, IF IC (U3), provides most of the adjacent channel selectivity by using integrated baseband low-pass filters. The input to the crystal filter is matched to the 1st mixer using components L36, L20, C35 and C36. The output of the crystal filter is matched to pin 2 of the IF IC using inductor L22 and the capacitive tap: C38 and C39.

Receiver Back End

The intermediate frequency (IF) is applied to the IF IC (U3), where it is down-converted, amplified, filtered, and demodulated to produce the recovered audio. This IF IC is electronically programmable, and the amount of filtering (which is dependent on the radio channel spacing) is controlled by the microcontroller. Additional filtering, which used to be provided externally by conventional ceramic filters, is replaced by internal filters in the IF IC. The IF IC uses a type of direct conversion process whereby the second LO frequency is very close to the IF frequency. The IF IC controls the second LO VCO and causes the VCO to track the first IF frequency, producing a phased-lock operation. The IF IC also provides a recovered signal-strength indicator (RSSI) and squelch output for use in other parts of the radio.

Transmitter

The 800MHz RF PA (U105) is a 5-stage amplifier. The RF power amplifier has a nominal input and output impedance of 50 ohms.

An RF input drive level of approximately +3dBm is supplied from the VCO buffer IC (U201) and applied to pin 1 of U105. The dc bias for the internal stages of U105 is applied to pins 2, 5, and 6 of the module. Pins 2 and 5 are switched through Q101, and pin 6 is unswitched B+ to the final amplifier stage. Power control is achieved through the varying of the dc bias to pins 3 and 4, the third and fourth amplifier stages of U105. The amplified RF signal leaves the PA module by way of pin 7 and is applied to the directional coupler, U104.

The purpose of U104 is to sample both the forward power and the reverse power. The reverse power will be present when other than a 50-ohm load exists at the antenna port. The sampling will be achieved by coupling some of the reflected power, forward or reverse (or both), to a coupled leg on the coupler. The sampled RF signals are applied to diode CR101 for rectification and summing. The resulting dc signal is applied to the ALC IC (U101 pin 2) as RFDET, to be used as a strength indicator of the RF signal being passed through the directional coupler, U104.

The transmit ALC IC, U101, is the heart of the power control loop. The REF V line (U101 pin 7), a dc signal supplied from the D / A IC (U102), and the RF DET signal described earlier, are compared internally in the ALC IC to determine the amount of C BIAS (pin 4) to be applied to the base of transistor Q110. Transistor Q110 responds to the base drive level by varying the dc control voltages applied to pins 3 and 4 of the RF PA; this action controls the RF power level of module U105. The ALC IC also controls the base switching to transistor Q101 by way of pin 12 (BIAS).

The D / A IC, U102, controls the dc switching of the transceiver board. The outputs of the D / A IC, SC1 and SC3 (pins 12 and 14 respectively), control transistor Q108; the D / A IC then supplies TX 5V and RX 5V to the transceiver board. The D / A also supplies the dc bias to the detector diode (CR101) by way of pin 7, and also the REF V signal to the ALC IC, U101.

Controller

Since the controller is the central interface between the various subsystems of the radio, and because of the controller's complexity, this section will be divided into two areas:

- the microcontroller and its functions, and
- the controller board circuit operation.

Microcontroller (U705)

The heart of the VISAR controller consists of a new generation Motorola microcontroller: U705. The microcontroller consists of 640 bytes of EEPROM, 1k bytes of RAM, and 32k of ROM. It operates in single-chip mode. The microcontroller is powered by a regulated 5V output from voltage regulator U708. The microcontroller clock is generated by the ASF IC, U701, which has an integral, programmable-clock synthesizer.

Functions

The microcontroller has two basic functions: interfacing to the outside world and controlling the internal workings of the radio. It interfaces directly to the side buttons, PTT, rotary volume potentiometer, audio jack, and the 9-pin side connector. It is constantly monitoring a numerous amount of inputs, interpreting any changes that may be occurring, and responding with commands controlling the rest of the radio. Some functions that it performs include:

- loading the synthesizer with the desired RF frequency
- turning the RF PA on or off,
- turning the microphone and speaker on or off,
- enabling and disabling audio and data paths, and
- generating tones.

Operations and operating conditions within the radio are interpreted by the microcontroller and fed back to the operator as audible (alert tone) indications of the radio's immediate status.

Microcontroller Clock Synthesizer

Upon power-up, and assuming that the ASF IC receives a proper 2.1 / 2.4MHz input at U701-E1 (which comes from the transceiver board), the ASF IC outputs a 3.6864MHz CMOS square wave on U701-D1. This UP CLK signal connects to the input of the microcontroller (U705-E3) as EXTAL. The microcontroller operates at 1 / 4 of this frequency, which in this case computes to 921.6 KHz.

After initialization, and upon power-up, the microcontroller programs the ASF IC to change the E-clock to 1.9872MHz. Therefore, soon after the controller is powered-up, serial data is sent to the ASF IC on signal line U701-E3, while select line U701-F2 is held low. After initialization, the UP CLK clock signal is 7.9488MHz on U701-D1.

SB9600 Serial Interface

The radio uses a proprietary multiprocessor serial protocol known as SB9600. This protocol allows the microcontroller in the system to interface with an external personal computer (PC) for RSS programming.

From a hardware standpoint, the external interface is the universal side connector's BUSY and DATA lines (P403 pins 8 and 7 respectively). The DATA signal is a bidirectional 0-5V RS-232 line using U705's integrated RS-232 asynchronous, serial communication interface (SCI) peripheral. The SCI TX line is U705-C2, and the SCI RX line is U705-C3. The SCI TX line and the SCI RX line are connected together; this provides the DATA signal, which is routed to the controller connector jack, J703 pin 10. The BUSY signal (at U705-A4) is an active-high, bidirectional signal, normally pulled down by 10k resistor, R737. The BUSY signal is routed to the controller connector jack, J703 pin 7.

A typical use of the SB9600 interface occurs when a PC runs the RSS software package, and the radio interface box (RIB), in programming the radio's codeplug. When the PC sends a command or data to the radio, observe the LH DATA line (U705-C3) toggling at a 9600 baud rate and the BUSY line going high when data is actually being sent. After the data transfer is complete, the busy line should idle low and the LH DATA line should idle high. The controller board also sends a power-up status message when it is first turned on. The SB9600 data being sent from the radio can be observed within a few milliseconds after power-up.

Option Select Lines

The two option select lines, OPT SEL 1 and OPT SEL 2 (P403 pins 1 and 2, respectively), are used to identify the presence of external accessories and also to key-up the radio. The logic level of these two lines is sensed at the microcontroller (U705) pins G7 and G8. Both of these ports are pulled-up internally, so the default state for these lines is high. This default state indicates the normal mode: no accessories are attached, and the internal speaker and microphone will be used. A brief summary of options is shown in Table 10-1. Generally, OPT SEL is pulled to a logic low; this indicates the presence of an external accessory, whether it is connected to the side connector port (P403), or to the 3.5mm accessory jack (J706). All audio will then be routed to the external accessory's speaker or earpiece.

With OPT SEL 1 at a logic low, OPT SEL 2 can be pulled to a logic low to externally key-up the radio. This will transmit audio from the accessory's microphone. The same two option lines are used to detect accessories and external PTT conditions, regardless of whether the side connector port, or the 3.5mm accessory jack, is being used. The microcontroller has no knowledge, or control, to which port (the microphone or the PTT) the external audio is routed. This routing is done through both mechanical switching in the 3.5mm jack and some detection circuitry. When no plug is inserted into the 3.5mm accessory jack, all signals and controls are routed to and from the side connector port. In this case, the appropriate OPT SEL 1 and OPT SEL 2 levels can be set externally by grounding pin 1 or pin 2, or both, on P403. With the plug inserted into the 3.5mm jack, OPT SEL 1 is automatically forced to a logic low, through some detection circuitry, to indicate the presence of an external accessory. In addition, the routing of external audio (now selected by low OPT SEL 1) is mechanically switched from the side connector port to the 3.5mm accessory jack. The jack overrides the side connector port's control of OPT SEL 1 and external audio. However, control is now shared for OPT SEL 2 and the external microphone.

The radio may now be remotely keyed by pulling low OPT SEL 2, either with the 3.5mm jack accessory, or directly on pin 2 of P403. This will route external audio from both the 3.5mm jack accessory microphone and pin 3 of P403. If no microphone is connected to P403 pin 3, the only active microphone will be the 3.5mm jack accessory microphone. OPT SEL 2 can be pulled low with the 3.5mm jack accessory by impedance-detection circuitry on the controller board. If the DC impedance from the external speaker line to ground falls below a certain threshold, OPT SEL 2 is pulled low.This configuration allows for multiplexing of the lines going through the 3.5mm jack, and permits the 3.5mm jack accessory to have external audio, external microphone, and an external PTT button through three contacts.

Table 10-1. Option Select Definition

Plug Inserted	OPT SEL 1	OPT SEL 2	Function
No	High	High	Normal operation internal speaker
No	High	Low	emerg / mandown*
No	Low	High	ext audio thru side
No	Low	Low	ext PTT side mic active
Yes	forced Low	High	ext audio thru jack
Yes	forced Low	Low	ext PTT jack mic active side mic active, if connected

*Not a supported feature

LED Control

The bi-color LED (CR801) is activated by microcontroller U705 in conjunction with the dual NPN transistor IC, U704. When either of the outputs (U705-H2 or U705-H1) is at a logic high, the corresponding output of U704 (pin 3 for the green LED, pin 6 for the red) is at approximately 4.3 volts. Note that it is possible to have both LED outputs on simultaneously, in which case the LED emits an orange / yellow light.

Liquid Crystal Display Module Interface

The VISAR LCD module is a two-digit display with one annunciator. It displays the current channel on which the radio is operating and notifies the user when scan has been accessed. The LCD module is powered by a 5-volt supply (from U708 pin 1 through J705 pin 1), and is accessed by the microcontroller through the chip select line (from U705-F3 through J705 pin 5). The LCD is driven by a 7.7kHz clock (from U705-E7 through J705 pin 6), and is updated from the microcontroller (U705 pads A2 and B2) through the SPI clock (J705 pin 3) and SPI data (J705 pin 4) lines. The LCD backlight can be enabled through J705 pin 7. The method used to turn on the backlight is user-programmable through the RSS.

Controller Board Circuit Operation

These circuits are involved in the controller board circuit operation:

- the transmit audio path between the microphone and the transmit RF section,
- the transmit data path between the microcontroller and the transmit RF section,
- the receive audio path between the receive RF section and the speaker,
- the receive data path between the receive RF section and the microcontroller, and
- the alert tone path between the microcontroller and the speaker.

The transmit and receive audio paths are disabled in the standby mode and selectively enabled by the microcontroller when the radio transmits or receives a signal. Also, there are minor differences in the function of the audio paths, depending on whether an internal or external (accessory) speaker or microphone, or both, is being used.

Transmit Audio Circuits

There are three major circuits in the transmit audio path. Some require enable lines, while others are active devices that are always operating. When the PTT is pressed, the radio will monitor the channel for traffic; this is called “smart PTT.” If the channel is not busy, the microcontroller will enable the path between the microphone and the RF section.

The microphone in the front cover (internal mic) and remote microphone (external mic) are FET electret types. They require a dc biasing voltage provided by resistors R702 and R703, respectively. The INT MIC audio is routed to module U701-B8. The EXT MIC audio is routed to module U701-A7. Logic inside the ASF IC selects one of the signals for amplification and processing.

Internal Microphone Path

The internal microphone (MK401) is located on the front cover of the radio and is connected to the controller board by way of controls flex P703, pin 15. On the controller, from connector J703 pin 15, the audio signal is routed to resistors R701 and R702. Resistor R702 performs dc biasing and resistor R701 provides input protection for the CMOS amplifier input. Filter capacitor C703 provides low-pass filtering to eliminate frequency components above 3kHz, and capacitors C704 and C705 serve as dc-blocking components. The high-pass filter, formed by capacitor C705 and resistor R700, attenuates objectionable low-frequency audio components of speech. The audio signal is passed on to the ASF IC, U701-B8.

External Microphone Path

The external microphone signal enters the radio by way of universal connector P703 pin 9, and is connected to the controller board through connector J703 pin 9. The external audio signal is routed through a filtering circuit composed of L701, C702, and R704, and, through dc blocking capacitor C706, is passed to the ASF IC, U701-A7. Resistor R756 provides dc bias for the stage.

PTT Sensing and Transmit Audio Processing

Pressing the internal PTT switch (S1) provides a ground path for the microcontroller by way of the controls flex to the controller connector P703 / J703 pin 18, and an internal pull-up resistor at the input of U705-H3. Pressing an external PTT switch provides a ground path for the input line (OPT SEL 2) by way of the universal connector (P403 pin 2). The ground is read by the microcontroller at U705-G8. When either PTT is sensed (internal or external), the microcontroller configures the ASF IC for the proper audio path. Inside the ASF IC, the audio input signal is amplified, filtered to eliminate components outside the 300-3000Hz voice band, pre-emphasized, and limited. The limited microphone audio is routed through a summer circuit, which adds PL or DPL sub-audio band modulation. Then, the limited microphone audio is channeled to a splatter filter to eliminate high frequency spectral components generated by the limiter. After the splatter filter, the audio is routed to two modulation attenuators, which are tuned for the proper amount of FM deviation. The transmit audio signal emerges from the ASF IC at U701-H8 and is dc-coupled to the synthesizer (U204 pin 5) on the transceiver board through connector jack J704 pin 3.

Transmit Path HearClear

For 900MHz controller boards, the HearClear IC (U601) along with its associated discrete components is placed on the board. The VHF, UHF, and the 800MHz controllers use the same PC board, but do not have these components placed. The HearClear IC provides proprietary circuitry to reduce audio noise and pops that can occur in a 2.5kHz deviation system. The noise and pops can be heard when the user is moving in a car.

The overall transmit audio path is the same for the non-HearClear path, except that the pre-amplified microphone audio is looped through the compressor. More specifically, the ASF IC pre-amp output (U701-A6), which is nominally 80 mVrms for an 8 mVrms mic input, is routed to U601- D3 via coupling capacitor C614.

The input signal is compressed in a 2:1 ratio relative to an 80 mVrms equal gain point. This means that, if the input signal is 80 mVrms, then the compressor output on U601-F3 will be 80 mVrms. However, if the input is 2dB higher than 80 mVrms, the output level will be 1dB higher than 80 mVrms. Likewise, if the input is 2dB lower than 80 mVrms, then the output will be only 1dB lower.

The output of the compressor is routed back to the ASFIC on pin U701-C7 through coupling capacitor C616. The ASF IC control line GCB4, which connects to U601-D1, controls whether compression is enabled or disabled. The HearClear IC enable is controlled by ASF IC line U701-A3. The compressor / expander enable line is usually low (disabled) unless the radio is keyed-up or receiving audio.

Transmit Data Circuits

There are three major types of transmit data: sub-audible data (PL / DPL), DTMF data for telephone communication, and Motorola Digital Communications (MDC) data for use in Motorola proprietary MDC systems. The deviation levels of the latter two are tuned by a 5-bit digital attenuator inside the ASF IC. Before the data can be generated and transmitted, a distinct set of tuning values (one for each of the three major data types) is programmed into the ASF IC.

Sub-audible Data (PL/DPL)

Sub-audible data is composed of low-frequency PL and DPL waveforms for conventional operation. Although it is referred to as “sub-audible data,” the actual frequency spectrum of these waveforms may be as high as 250Hz, which is audible to the human ear. However, the radio receiver filters out any audio below 300Hz, so these tones are never heard in the actual system.

Only one type of sub-audible data can be generated by U701 at any one time. Using the serial peripheral interface (SPI), the microcontroller programs the ASF IC to set up the proper low-speed data deviation and select the PL or DPL filters. The microcontroller then generates and produces a square wave at U705-C4, PA5, which strobes the ASF IC PL / DPL encode input at U701-C3. Module U701 reacts to the strobe input by generating a staircase approximation to a PL sine wave or the DPL data pattern. This internal waveform is low-pass filtered and summed with voice or data. The resulting waveform appears at U701-H8, VCO ATN, where it is sent to the transceiver board, as previously described for transmit audio.

DTMF Data

DTMF data is a dual-tone waveform used during phone interconnect operation. There are seven frequencies; four are in the low group (697-941Hz) and three in the high group (1209-1477Hz). The high-group tone is generated by the microcontroller (U705–B9), then strobes the ASF IC (U701–G1) at six times the tone frequency for tones lower than 1440Hz; or at twice the frequency for tones higher than 1440Hz. The low-group tone is generated by the microcontroller (U705-C8), then strobes the ASF IC (U701-G2) at six times the tone frequency. Circuits inside module U701 sum the low-group and high-group tones (with the amplitude of the high-group tone being approximately 2dB greater than that of the low-group tone) and send the summed signal through a pre-emphasis network. The resulting signal is routed through a summer and splatter filter. After filtering, the signal is channeled through modulation attenuators and sent from the ASF IC to the transceiver board. The signal path is from U701-H8 through the controller / interconnect flex connector (J704 / P704 pin 3), through the interconnect flex, and through the interconnect flex / transceiver connector (P301 / J301 pin 3) to the RF synthesizer (U204). The input signal is VCO MOD.

MDC Data

The MDC signal follows exactly the same path as the DTMF high-group tone. MDC data utilizes minimum-shift keying (MSK) modulation, in which a logic zero is represented by one cycle of a 1200Hz sine wave and a logic “one” is represented by 1-1 / 2 cycles of an 1800Hz sine wave. To generate the data, the microcontroller first programs the ASF IC (U701) to the proper filter and gain settings. It then begins strobing module U701-G1 (TRK CLK IN) with a square wave (from U705-B9, PH0) at the same baud rate as the data. The output waveform from U701 is fed to a post-limiter, then to a summer block, and then to a splatter filter. The resulting signal (using the same signal path as the DTMF data described in the previous paragraph) is routed through modulation attenuators and sent from the ASF IC to the transceiver board.

Receive Audio Circuits

The major circuits in the receive audio path are the ASF IC (U701) and the audio PA (U702). The ASF IC is a SPI programmable device, while the audio PA has direct control lines.

The radio’s transceiver circuits are constantly producing an output at the discriminator. In the conventional standby mode, the radio’s receiver is always monitoring the squelch line or sub-audible data, or both. The raw discriminator input signal (DISC) from the transceiver board enters the controller board on connector jack J704 pin 10. In addition to the raw discriminator signal, the transceiver board’s IF IC also provides a pre-filtered version of the discriminator signal, SQ OUT; SQ OUT is dedicated to the ASF IC’s squelch-detect circuitry.The SQ OUT signal enters the controller board by way of connector jack J704 pin12, and is routed to the ASF IC, U701-H7. When the microcontroller acknowledges it has received the proper data or signal type for unsquelching, it sets-up the receive audio path and sends data for the ASF IC (U701) to process.

U701 Audio Processing and Digital Volume Control

The signal (DISC) enters the ASF IC (U701-J7) for further processing. Inside the IC, the signal first passes through a low-pass filter to remove any frequency components above 3000Hz, and then through a high-pass filter to strip off any sub-audible data below 300Hz. Next, the recovered audio passes through a de-emphasis filter to reduce the effects of FM noise. Finally, the IC amplifies the audio and passes it through an 8-bit programmable attenuator, whose level is set in accordance with the voltage sensed on the volume potentiometer. The potentiometer is connected to U705-J5, PE1. After passing through the 8-bit digital attenuator, the audio goes to a buffer amplifier and exits the module at U701-J4 (RX AUD OUT), where it is routed to the audio PA module, U702.

Differential Speaker Audio Amplification

The final stage in the receive path is the audio amplifiers that drive either the internal or external speakers. Each speaker is driven using a dual-amplifier arrangement. Since one amplifier can be shared between the two speakers, only three total amplifiers are needed inside the audio PA IC, U702. The audio signal is coupled into the amplifiers on U702-C6 (AMP IN).

There are two enable lines controlling the three audio amplifies in module U702. They are, the external / internal speaker (EXT / INT SPKR) line, and the power amplifier enable (AMP EN) line. The EXT / INT SPKR input at U702-C1, which is used to control the phase of the internal or external amplifier, comes from U701-A2. The AMP EN input at U702-D1, which enables all three amplifiers, comes from U701-B3. The EXT / INT SPKR line is active-low, while the AMP EN line is active-high. The microcontroller determines if the audio should be routed to the internal or external speaker by reading option select line 1 (OPT SEL 1) at pin 1 of the universal connector, P403. When the receive path is enabled, two of the three amplifiers in U702 are turned on. The three amplifiers are the internal, external, and common. The common amplifier is always 180 degrees out of phase with one of the other, enabled, amplifiers. The nominal voltage for rated audio is 3.46Vrms, and the nominal audio input to U702 is 88.7mVrms, when rated audio output is obtained.

Receive Path HearClear

For 900MHz controllers, the raw discriminator (which contains both audio and sub-audible data) is routed to U601-E4, the input to the flutter-fighter circuit inside U601. The purpose of this section is to eliminate any noise bursts in the recovered audio due primarily to multipath fades. The IC monitors the noise content of the discriminator as well as the received signal-strength indicator (RSSI) line from the RF board. The IC then determines if the discriminator needs any noise reduction (attenuation) and processes the signal accordingly.

The output of the flutter-fighter is U701-F4. The flutter-fighter circuit is controlled by U600-E3 and is active high. If the control line is low, the circuit will still pass audio, but will behave like a linear 0dB gain stage without any noise reduction function.

In expansion mode, the de-emphasized audio is routed through the HearClear expander and back to the ASF IC. The audio enters the expander on pin U601-C1 and exits on U601-A2. The expander input signal is expanded in a 1:2 ratio (which cancels the 2:1 compression on the transmit) relative to a 200 mVrms equal gain point. This means that if the input signal is 200 mVrms, then the output on U601-A2 will be 200 mVrms. However, if the input is 1dB higher than 200mVrms, then the output level will be 2dB higher than 200 mVrms. Likewise, if the input is 1dB lower than 200 mVrms, then the output will be 2dB lower. This circuit greatly improves the signal-to-noise ratio.

Control line U701-D1 controls whether expansion is enabled or disabled. If this signal is at a logic low, then the expander still passes audio, but it behaves like a pure, linear 3dB gain stage.

Receive Data Circuits

The ASF IC (U701) is used to decode all receive data; this includes PL, DPL and MDC. The “decode” process for each data type typically involves low-pass or band-pass filtering, signal amplification, and routing the signal to a comparator. The comparator outputs a logic zero or one signal. The discriminator output from the transceiver board is routed to U701-J7 through the coupling capacitor C709. Inside module U701, the data is filtered according to the data type (high-speed [HS] data or low-speed [LS] data), then hard-limited to a 0-5V digital level. The high-speed data output (MDC) appears at U701-G4, where it interconnects with the microcontroller, U705-C5, PA0. The low-speed limited data output (PL, DPL) appears at U701-A4, where it interconnects with U705-B5. For example, if the radio is receiving 192.8Hz PL, the discriminator should contain a 192.8Hz sine wave at about 53 mVrms, and the limited PL output should be a 192.8Hz square wave. While the radio is decoding PL, DPL, the microcontroller also outputs a sampling waveform on U705-C4, PA5. The sampling waveform is then routed to U701-C3; this is the same line used to generate transmit PL or DPL data. This sampling waveform is a square wave between 1000Hz and 2000Hz.

Alert Tone Circuits

When the microcontroller provides feedback to the operator on the status of various conditions (for example, feedback on low battery, circuit failures, etc.), it sends an alert tone to the speaker. It does this by sending data to ASF IC U701; the ASF IC sets-up the audio path to the speaker for alert tones. The alert tone itself can be generated in one of two ways: internally by the ASF IC, or externally using the microcontroller and the ASF IC. The allowable internal alert tones are 300Hz, 900Hz, and 1800Hz. For external alert tones, the microcontroller can generate any tone within the 100-3000Hz audio band. The microcontroller does this by toggling the output line, U705-D4 (PA6); this line is also used to generate low-group DTMF data. Inside the ASF IC, the signal is routed to the external input of the alert tone generator. The output of the generator is summed into the audio chain after the RX audio de-emphasis circuit. Inside module U701, the tone is amplified, filtered, and passed through the 8-bit digital volume attenuator. The tone signal, from ASF IC U701-J4, is then routed to the audio PA, as is the receive audio.

Section 11
Troubleshooting

Introduction

The technician servicing VISAR portable radios needs to localize a malfunctioning circuit before the defective component can be isolated and replaced. Since localizing and isolating a defective component consumes the most servicing time, a thorough understanding of the circuits will aid the technician to perform efficient servicing. The technician must know how one function affects another; he, or she, must be familiar with the overall operation of the radio, and the procedures required to quickly place the radio back in operation.

The radio functional block diagrams, schematic diagrams, and troubleshooting charts provide valuable information for troubleshooting purposes. The functional diagrams provide signal flow information in a simplified format, while the schematic diagrams provide the detailed circuitry and biasing voltages required for isolating malfunctioning components. Using the diagrams, troubleshooting charts, and deductive processes, a suspected circuit might be easily located.

Performance checks for the receiver, such as 20dB quieting, 12dB SINAD, noise, and PL squelch sensitivity, will help to determine if the radio should be analyzed. These should give the technician a general indication of where the problem is located.

After the general problem area of the radio has been identified, careful use of a dc voltmeter, RF millivoltmeter, and an oscilloscope should isolate the problem.

Troubleshooting Procedure

Each time the radio is turned on, a microcontroller self-test occurs. A 1600Hz alert tone is generated for approximately 500 milliseconds to indicate that the microcontroller is functioning properly. If the alert tone is not heard (and the alert tones have not been disabled using the radio service software), there is a problem with the radio.

Following the microcontroller self-test, a synthesizer self-test occurs. A continuous 1600Hz alert tone is generated if the synthesizer test is not successful. If this condition occurs (continuous alert tone) refer to the VCO / synthesizer troubleshooting chart.

When a radio performs unsatisfactorily, the following procedures should help localize the fault.

1. Check Batteries

   The first step in localizing a problem is to check the battery voltage under load. With the transmitter turned on (keyed), check the battery voltage. A convenient way to do this is to remove the front cover and monitor the B+ line with a voltmeter (with respect to ground). The measured load voltage should not be less than seven volts. Even though the transmitter may operate at a lower voltage, operation would be marginal and of short duration. Low-voltage transmit operation is indicated by the flashing LED on the front of the radio. If the measured voltage is zero volts, check the battery. The recommended procedure is to replace, or recharge, the battery if the voltage is below seven volts under load.

2. Alignment

   Strict adherence to the published procedures is a prerequisite to accurate alignment and proper evaluation of the performance of the radio. The selection of test equipment is critical. If recommended radio testing equipment is not available, check with a Motorola authorized area representative to be sure the equipment is of equivalent quality.

   The service technician must observe good servicing techniques. The use of interconnecting cables that are too long, poorly positioned (dressed), or improperly terminated will result in erratic meter readings. As a result, it will not be possible to tune the radio to the desired specifications.

   Use the recommended test equipment setup and proper connections for alignment and adjustments. Refer to the detailed procedures supplied in the applicable service manual.

3. Check Overall Transmitter Operation

   If the battery voltage is sufficient, check the overall performance of the transmitter. The RF power output measurement is a good overall check of the transmitter. This check indicates the proper operation of the transmitter amplifier stages. A properly tuned and operating transmitter will produce the rated RF output into a 50-ohm load with a dc input of 7.5 volts (refer to “Transmitter Alignment Procedure,” located in the service manual, for specific RF output). If the power is less than the rated RF output, refer to the applicable transmitter troubleshooting chart.

4. Check Overall Receiver Operation

4A. 20dB Quieting Sensitivity Test

A good overall check of receiver operation is the 20dB quieting, sensitivity measurement. This check will indicate that the receiver has sufficient gain and that all of the included circuitry is working properly. The quieting signal is the RF signal input necessary to reduce the audio output at the speaker by 20dB. This measurement should be made with no modulation. It will be necessary to hold down side button 2 during this test; otherwise, the radio's squelch circuitry will remove the noise from the speaker.

Make the actual measurement (using an ac voltmeter) by setting the noise voltage across the test-box speaker load (with no RF signal received at the antenna) to one-half (1/2) of the rated audio power output (1.85Vrms). To reduce the noise-output voltage to one-tenth (1/10) of the previous reading, sufficient carrier signal from a generator is introduced by way of the antenna port. If all of the circuitry is operating correctly, this reading should be 0.5µV or less. If the radio does not meet this specification, try to retune the receiver using the procedure indicated in the service section. If this does not solve the problem, refer to the receiver troubleshooting chart.

4B. 12dB SINAD

This procedure is a standard method for evaluating the performance of an FM receiver, since it provides a check of the RF, IF, and audio stages. The method consists of finding the lowest modulated signal necessary to produce 50% of the radio's rated audio output with a 12dB, or better, ratio of signal + noise + distortion / noise + distortion. This is termed "usable sensitivity."

To perform this measurement, connect the leads from a SINAD meter to the audio output of the test box. Set the Motorola service monitor, or RF signal generator, to output a 1-millivolt signal. Modulate the RF signal with a 1kHz tone at 3kHz deviation for VHF, UHF, and 800MHz; use 1.5kHz deviation for 900MHz (if applicable). Introduce the signal to the radio at the exact channel frequency through the antenna port. Set the volume control for rated audio output (3.74Vrms). Decrease the RF signal level until the SINAD meter reads 12dB. The signal generator output (12dB SINAD measurement) should be less than 0.35µV. If the radio does not meet this specification, try to retune the receiver using the procedure indicated in the service section. If this does not solve the problem, use the procedure in the receiver troubleshooting chart.

Voltage Measurement and Signal Tracing

To aid in troubleshooting, ac and dc voltage readings are provided (in red) on the transceiver schematic diagram in the service section. When making these voltage checks, pay particular attention to any notes that may accompany the voltage reading of a particular stage.

⚠ CAUTION

When checking a transistor or module, either in or out of the circuit, do not use an ohmmeter having more than 1.5 volts dc appearing across the test leads or an ohms scale of less than x 100.

If receiver sensitivity is high, or if the RF power output is lower than normal for a fully tuned transceiver, the dc voltages on the printed circuit board should be checked. These voltages should be referenced to ground.

It is recommended not to replace a transistor or module before a thorough check of the components is made. Read the voltages around the suspected stage. If these voltages are not reasonably close to those specified, the associated components should be checked.

⚠ CAUTION

The microcontroller is a static-sensitive device contained on the controller flex assembly. DO NOT attempt to troubleshoot or disassemble the microcontroller/controller flex assembly without first referring to the "Safe Handling of CMOS Devices" paragraph in the MAINTENANCE section of the manual.

A low impedance meter should not be used for measurement; a high impedance meter is recommended. If all dc voltages are correct, the signal should be traced through the circuit to show any possibility of breaks in the signal path.

Troubleshooting Charts

The troubleshooting charts on the following pages will help isolate troubles in the different sections of the radio. Start at the top of the appropriate chart and make the checks as indicated. Most malfunctions will respond to the systematic approach used in troubleshooting.

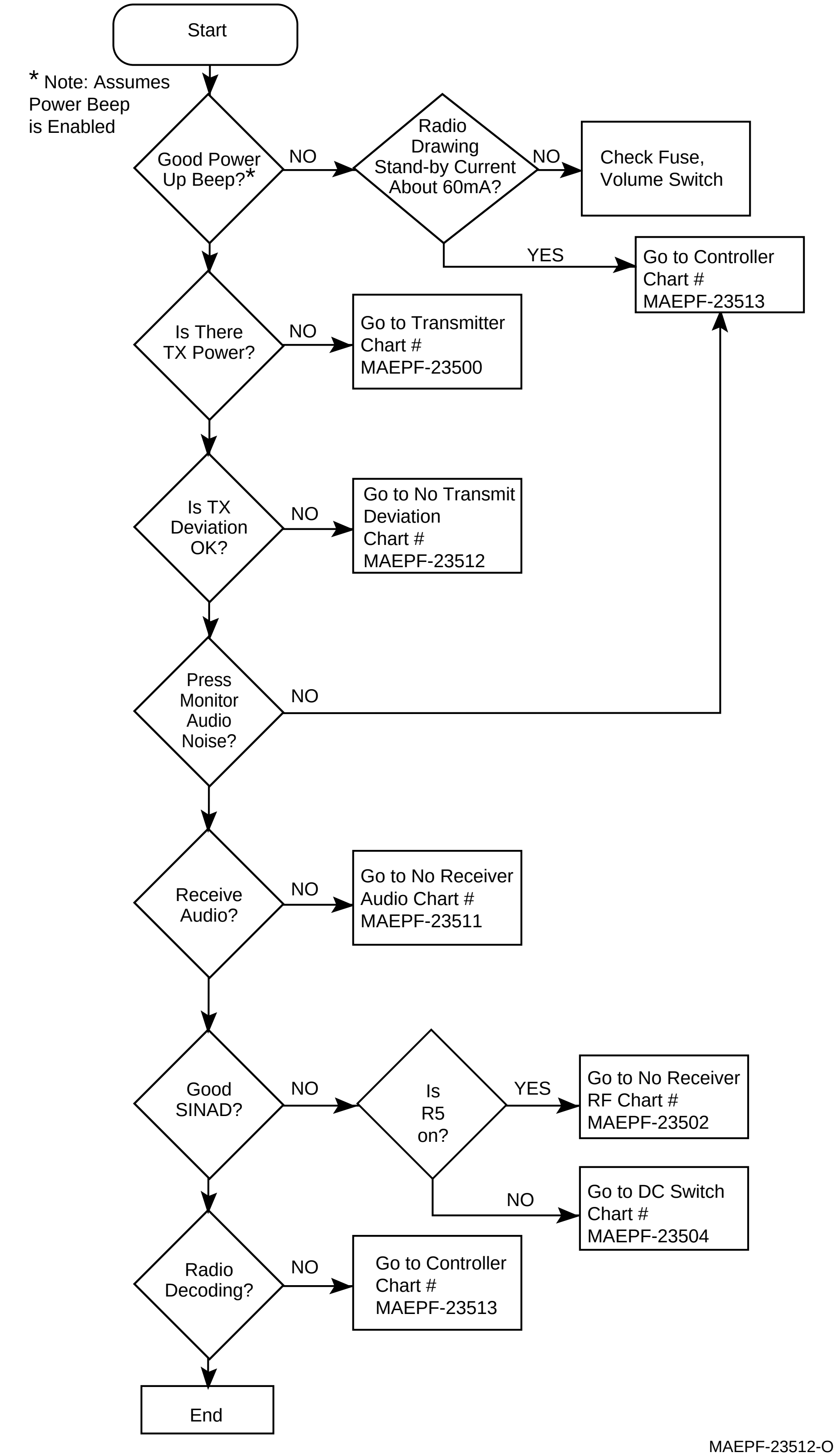


Figure 11-1. Troubleshooting Flow Chart VHF/UHF Transceiver Controller

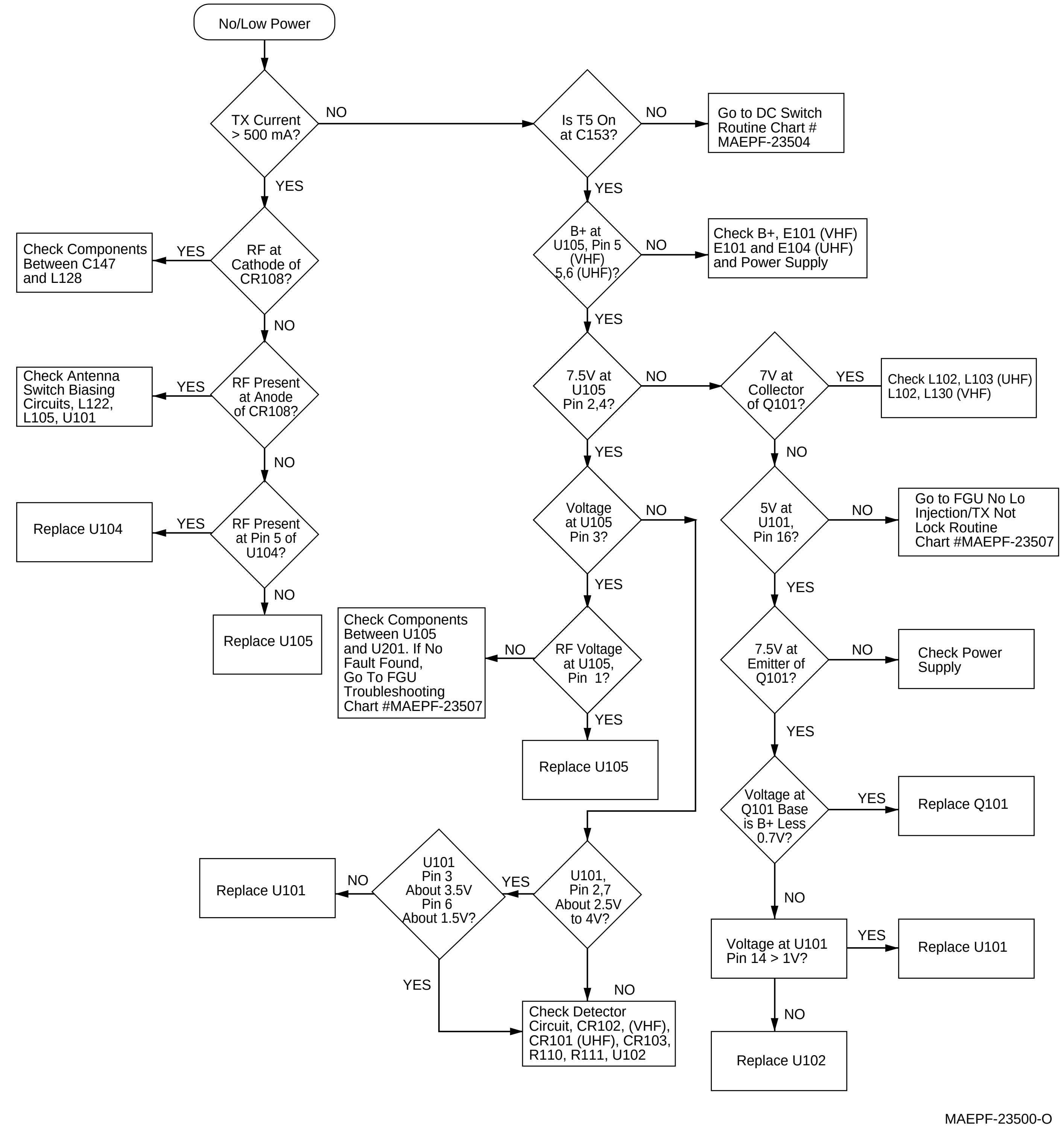


Figure 11-2. Troubleshooting Flow Chart VHF/UHF Transmitter RF

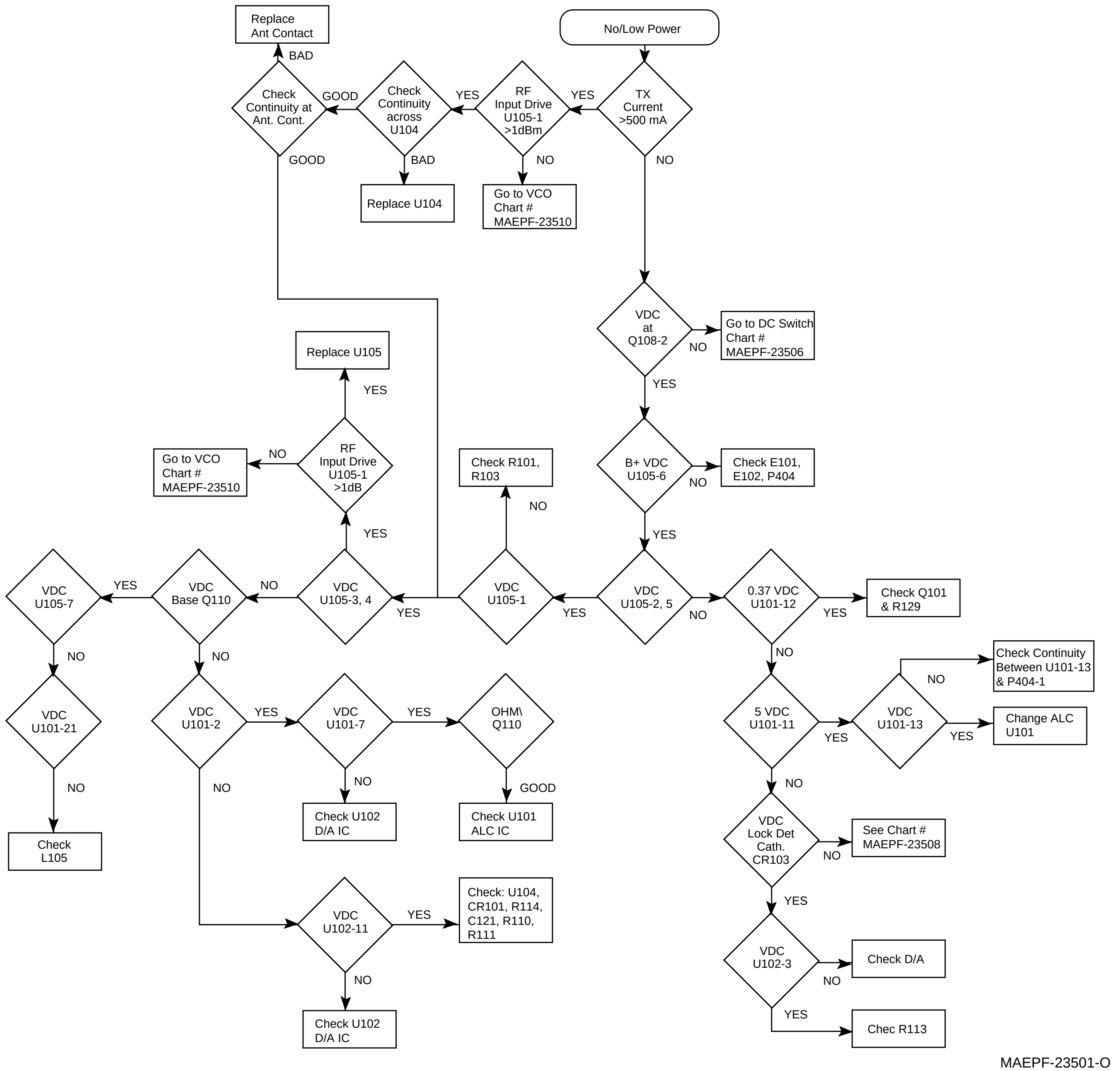


Figure 11-3. Troubleshooting Flow Chart 800/900MHz Transmitter RF

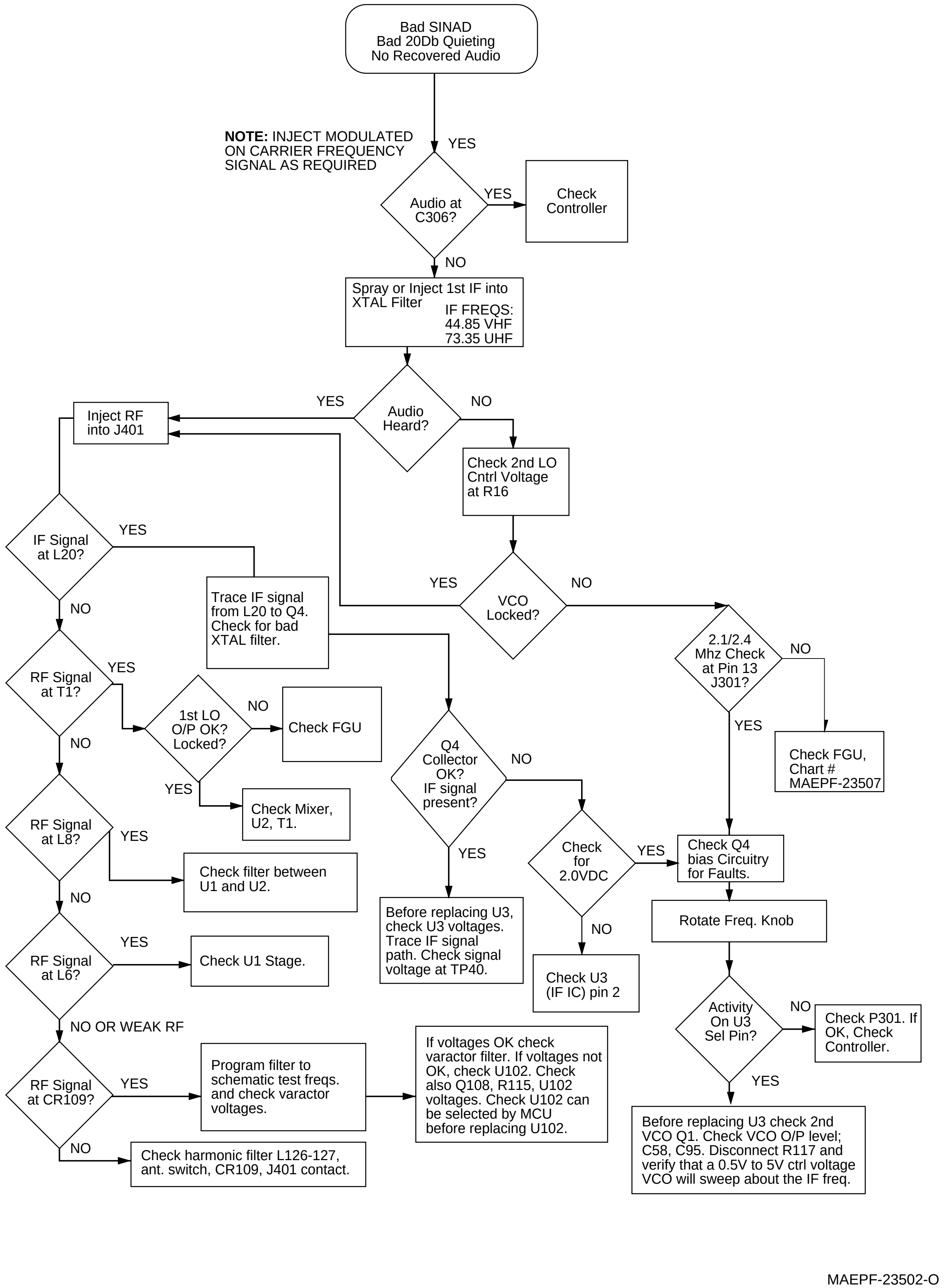


Figure 11-4. Troubleshooting Flow Chart VHF/UHF Receiver RF

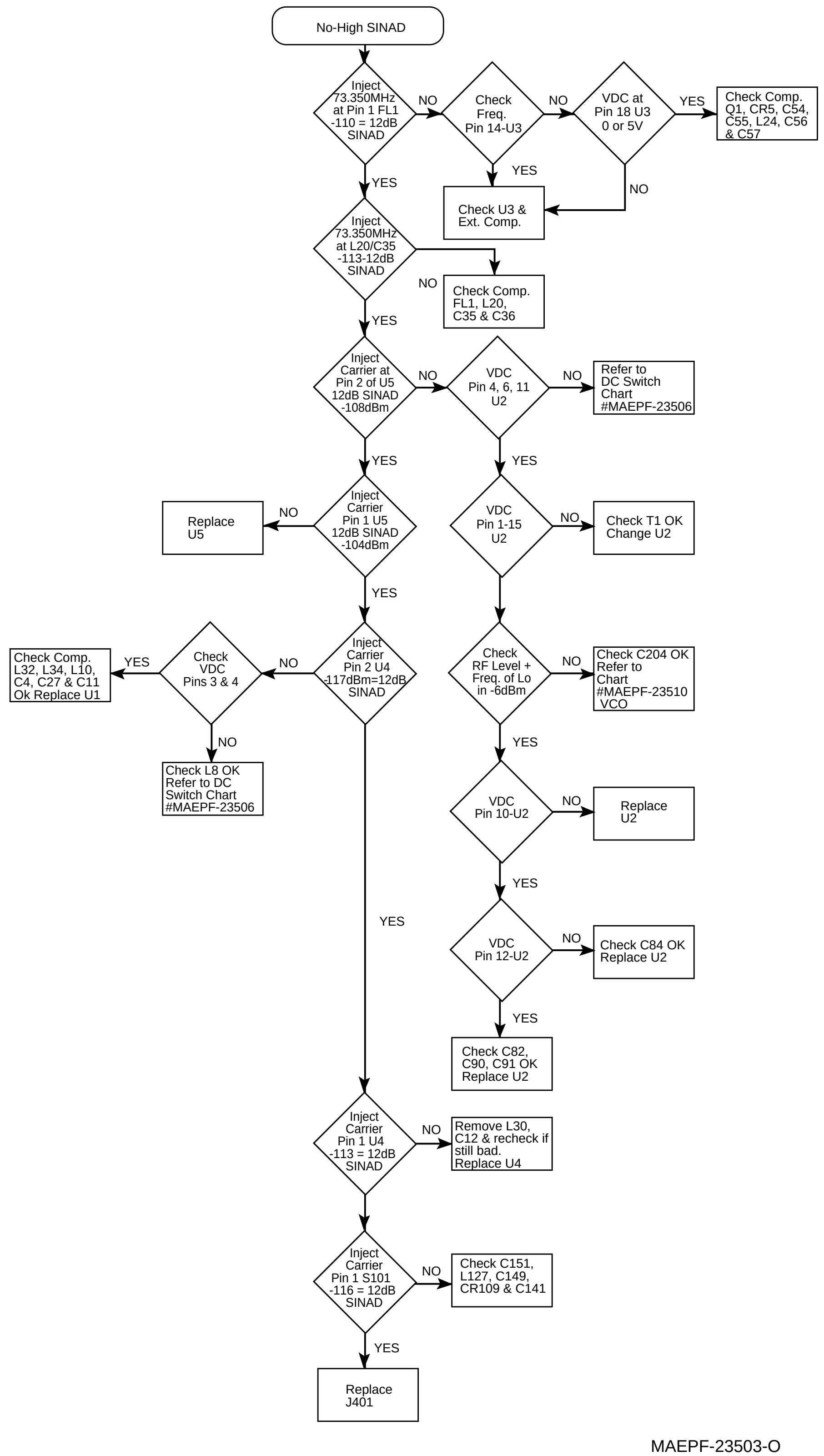


Figure 11-5. Troubleshooting Flow Chart 800/900MHz Receiver RF

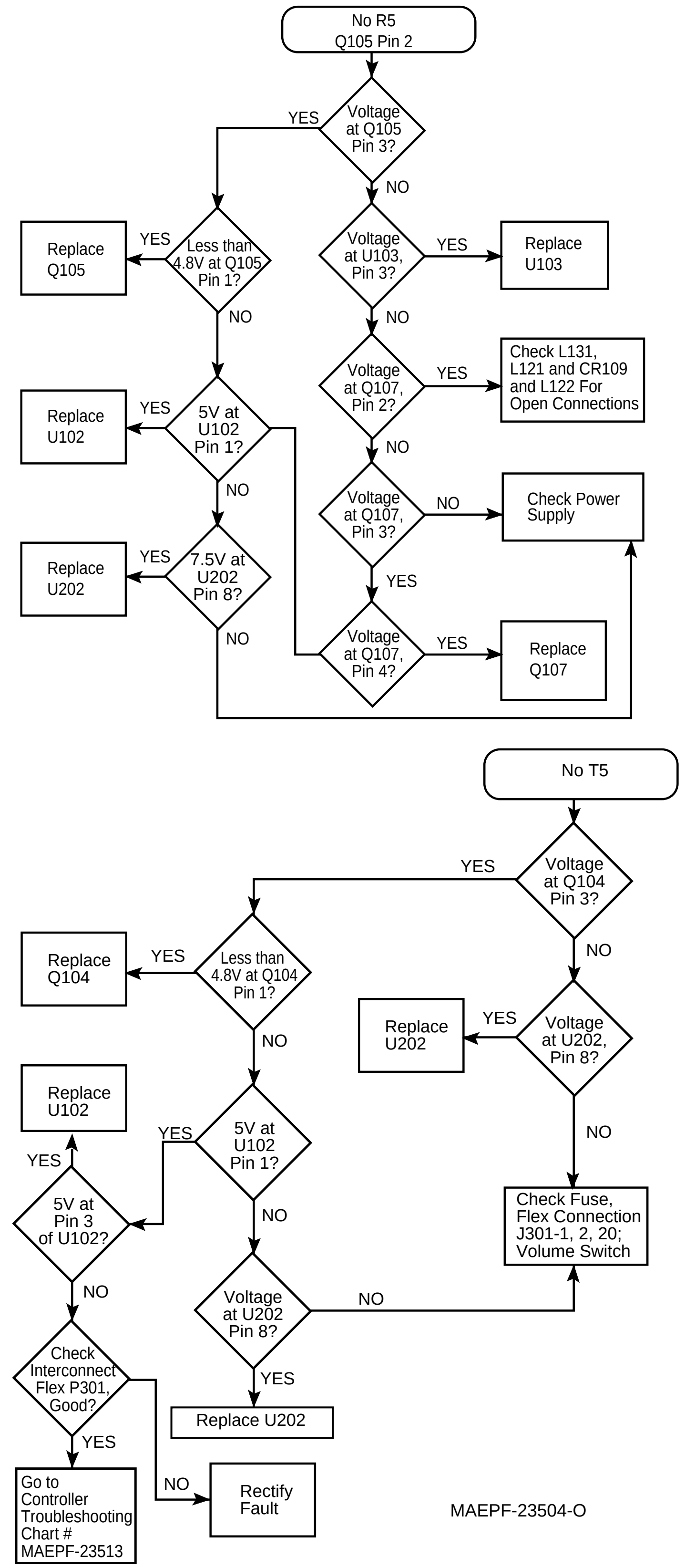


Figure 11-6. Troubleshooting Flow Chart VHF/UHF DC Switch

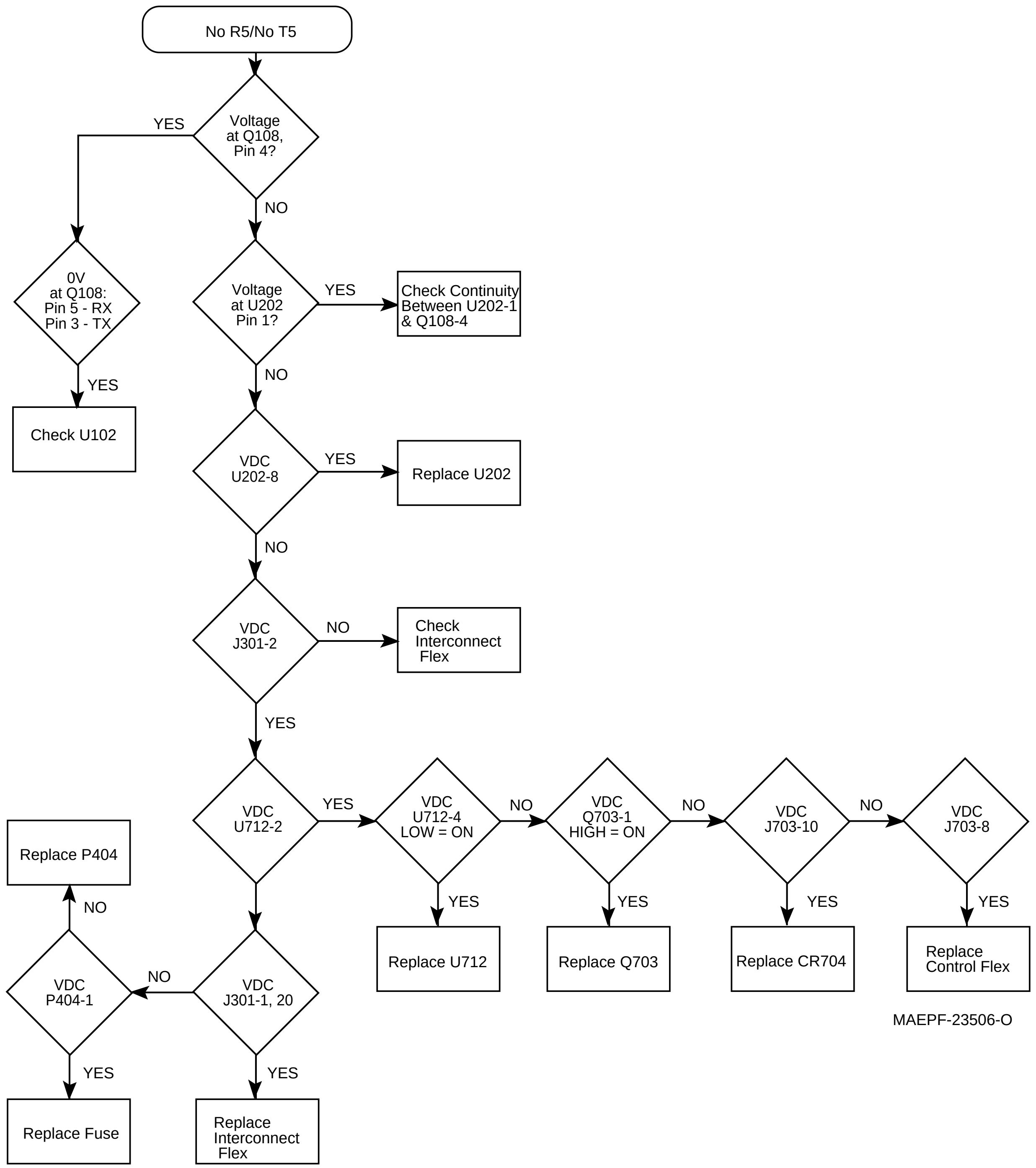
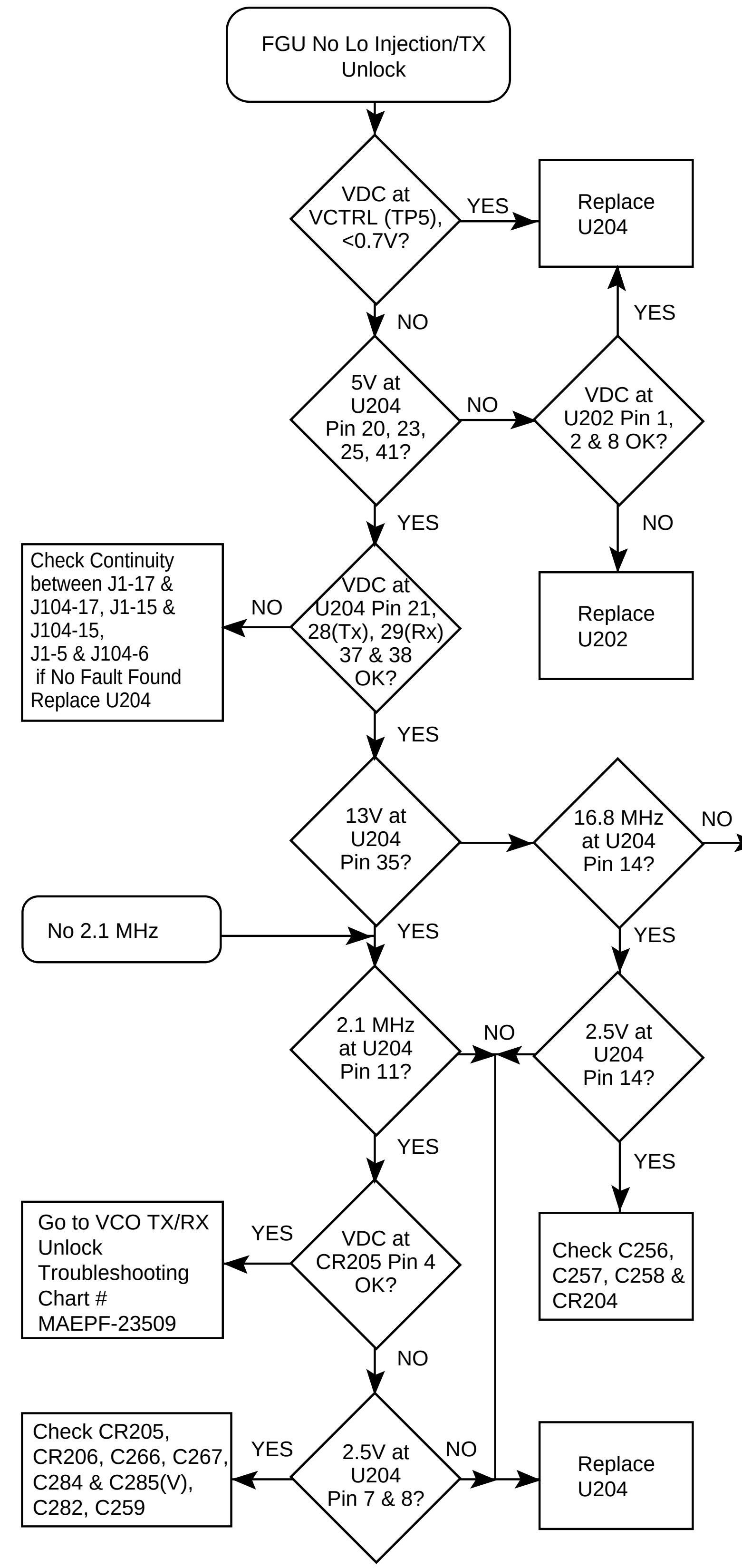


Figure 11-7. Troubleshooting Flow Chart 800/900MHz DC Switch



IC	PIN	VOLTAGE
U202	1, 2 8	5V 7.5V
U204	21 28 28 29 29 38 38 37 37	1.6V 1.7V (VHF TX) 1.6V (UHF TX) 1.8V (VHF RX) 1.6V (UHF RX) 4.5V (TX) 0.7V (RX) 4.5V (HIGH END) 0V (LOW END)
CR205	4	-7.5V (HIGH END) 0V (LOW END)

MAEPF-23507-O

Figure 11-8. Troubleshooting Flow Chart VHF/UHF Frequency Generation Unit

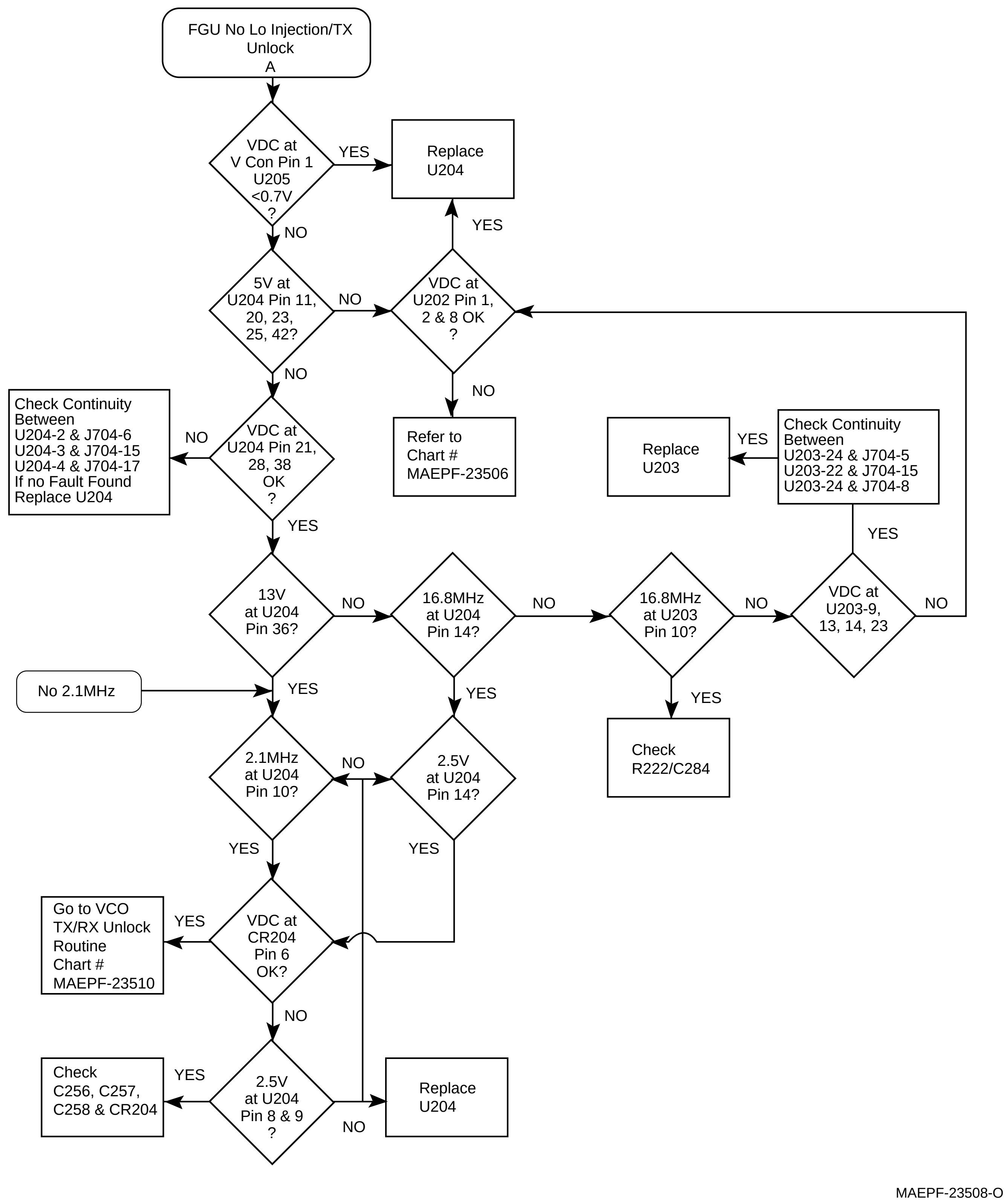


Figure 11-9. Troubleshooting Flow Chart 800/900MHz Frequency Generation Unit

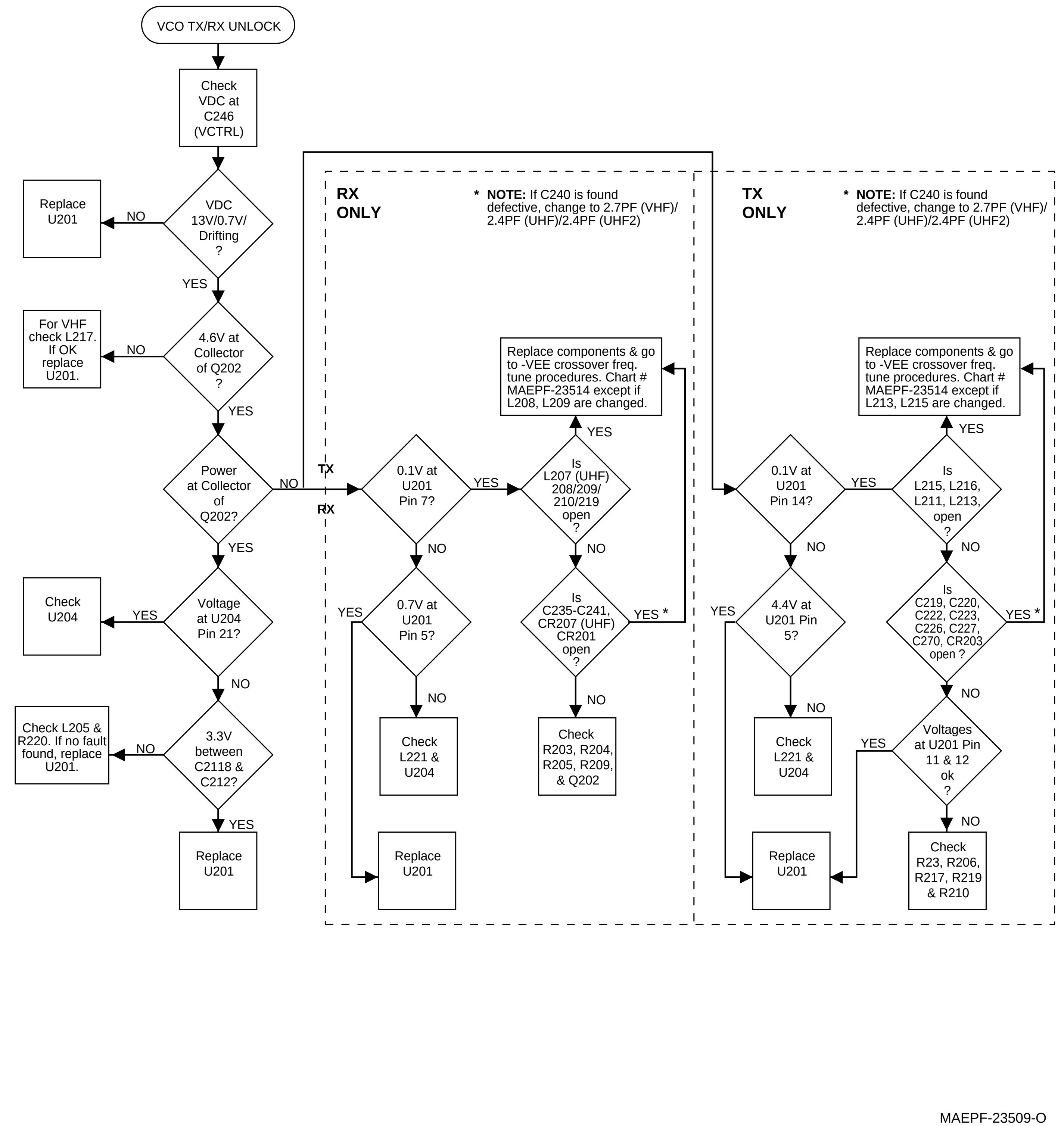


Figure 11-10. Troubleshooting Flow Chart VHF/UHF Voltage-Controlled Oscillator

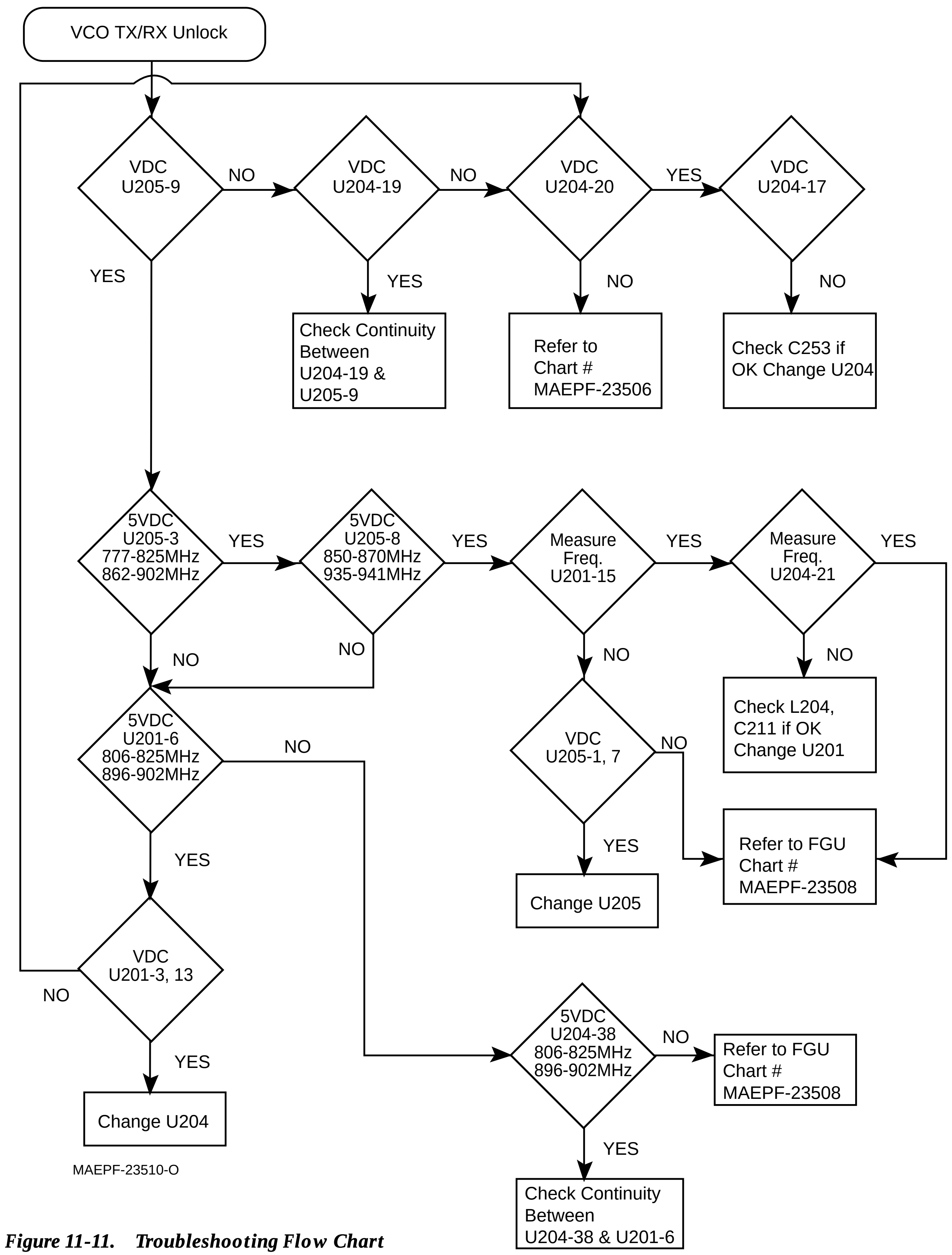


Figure 11-11. Troubleshooting Flow Chart 800/900MHz Voltage-Controlled Oscillator

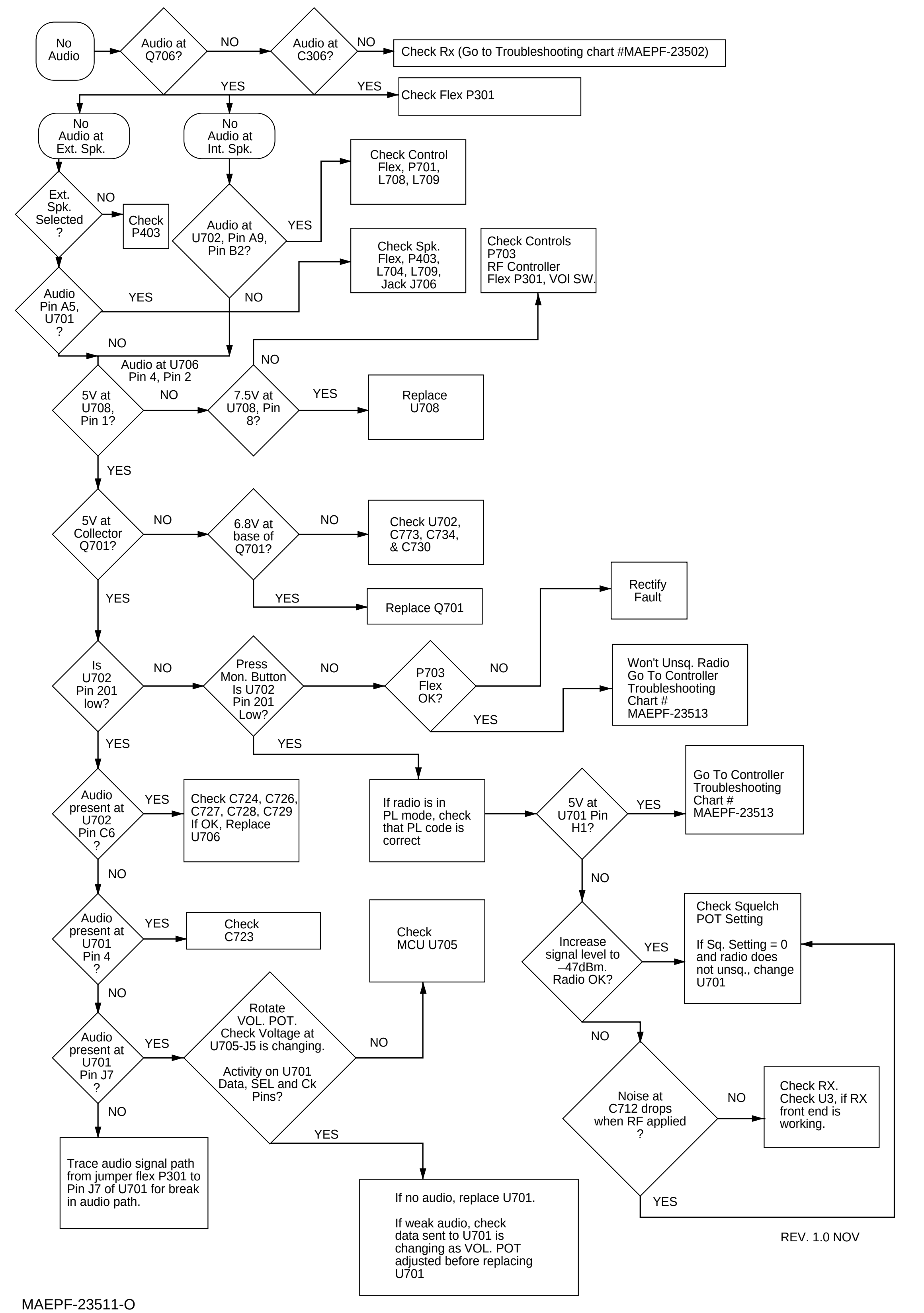


Figure 11-12. Troubleshooting Flow Chart VHF/UHF No Receive Audio

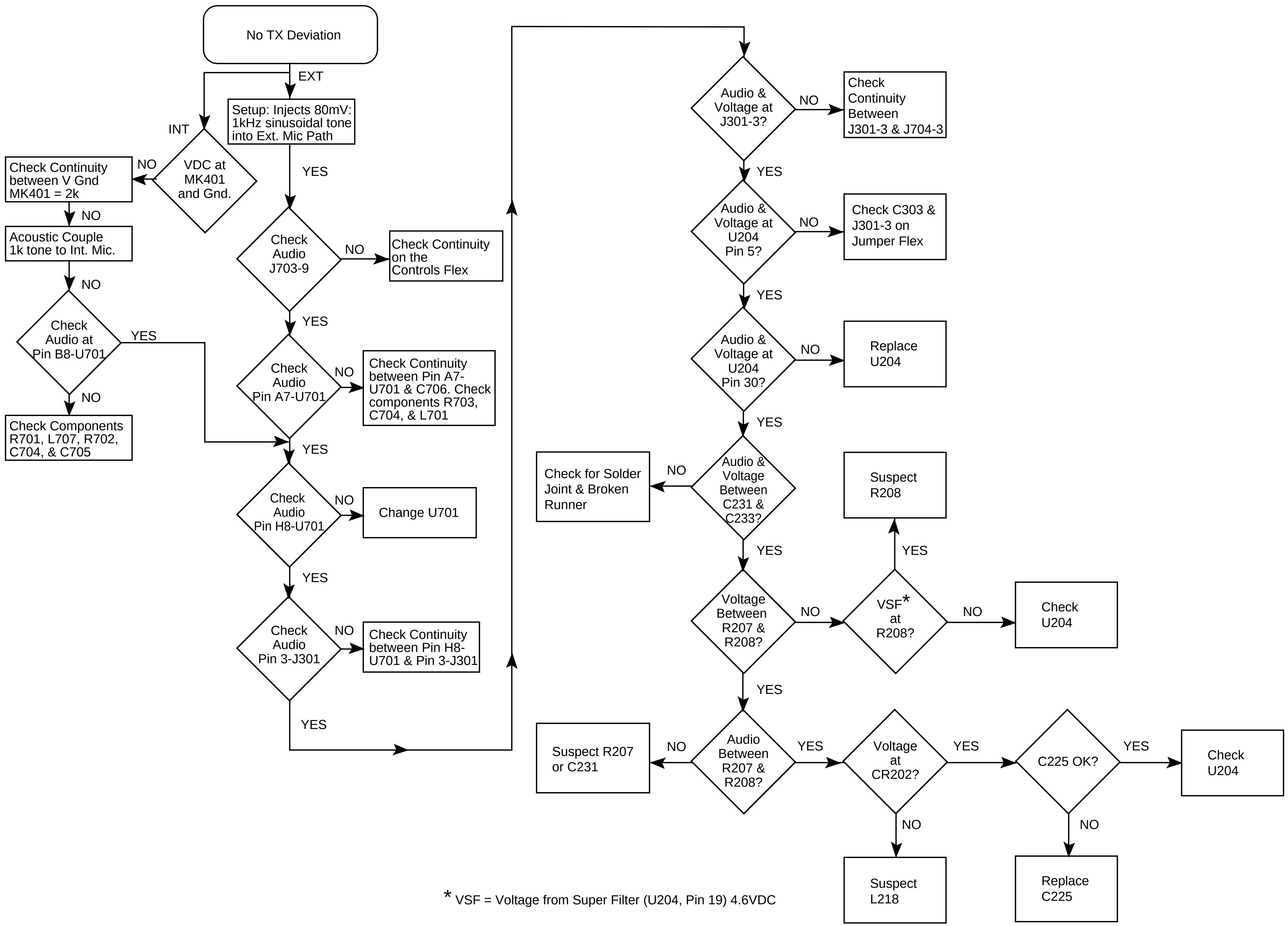


Figure 11-13. Troubleshooting Flow Chart VHF/UHF No Transmit Deviation

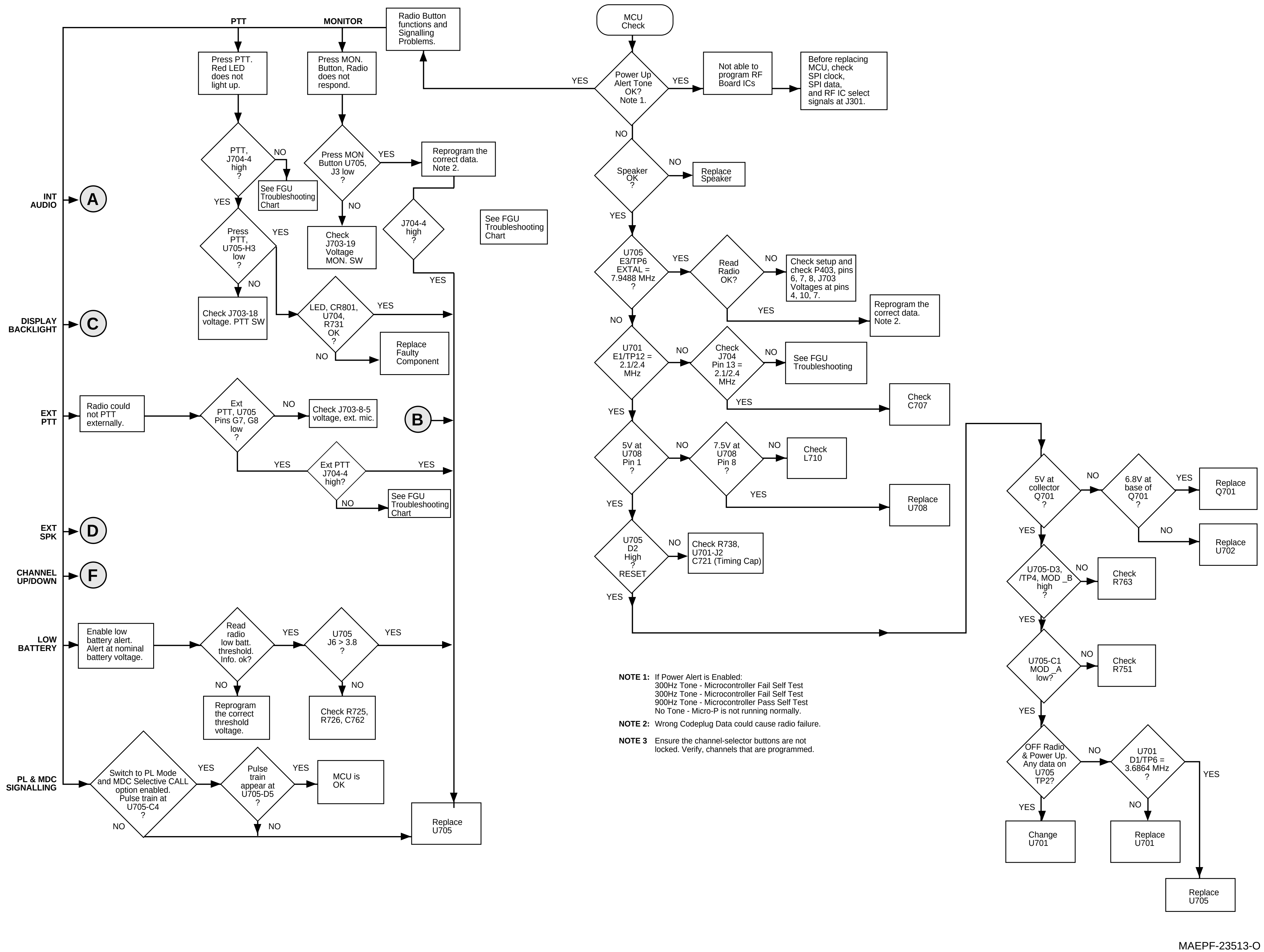
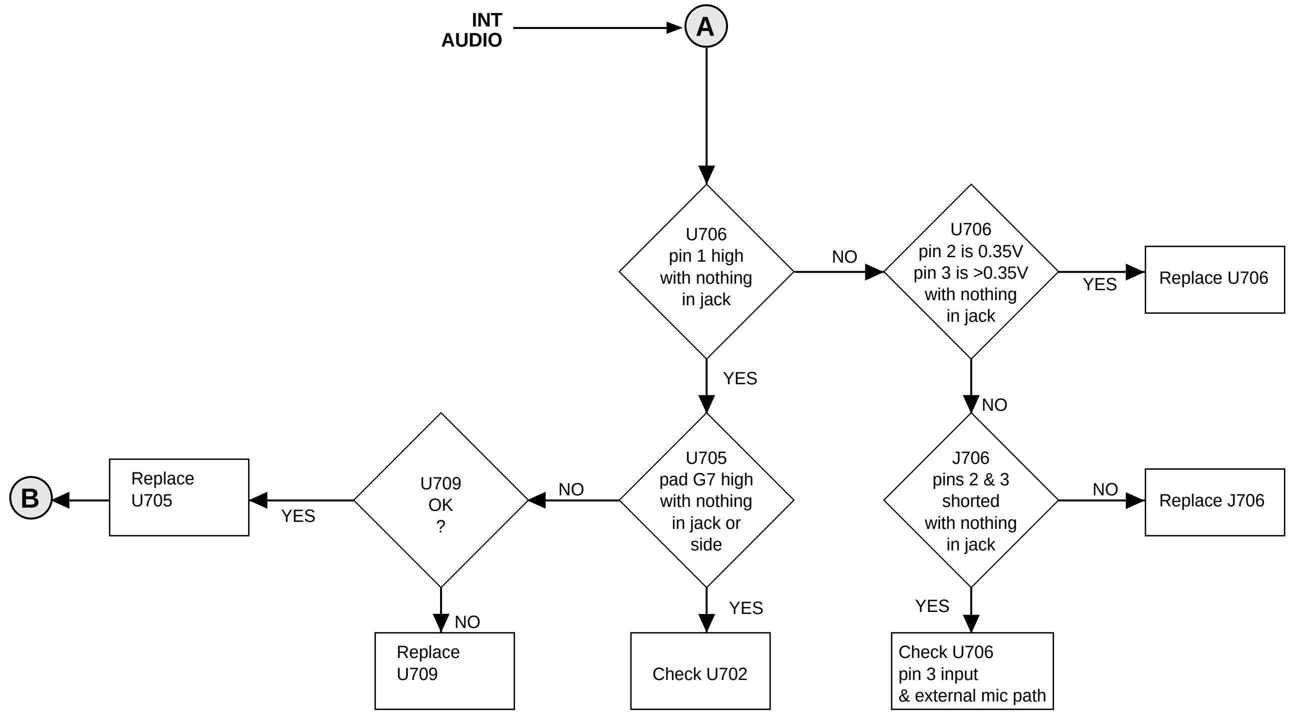
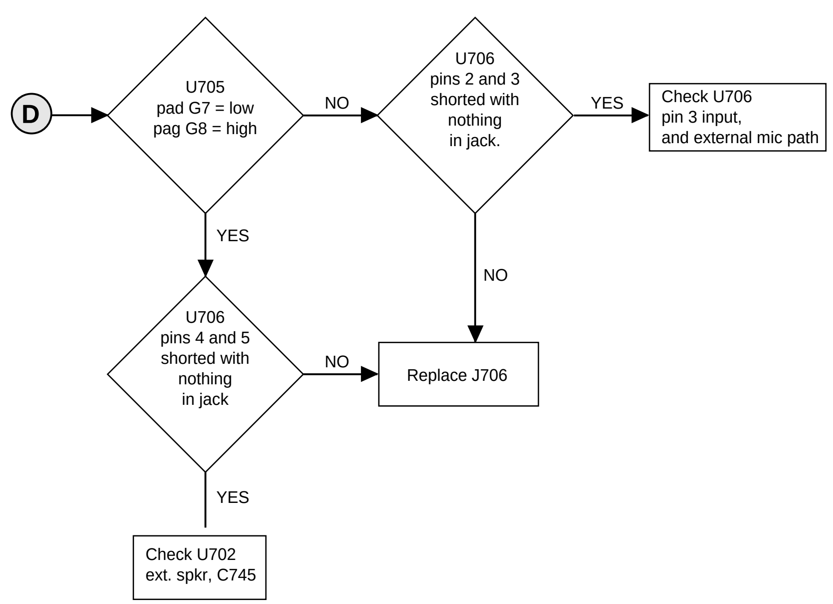


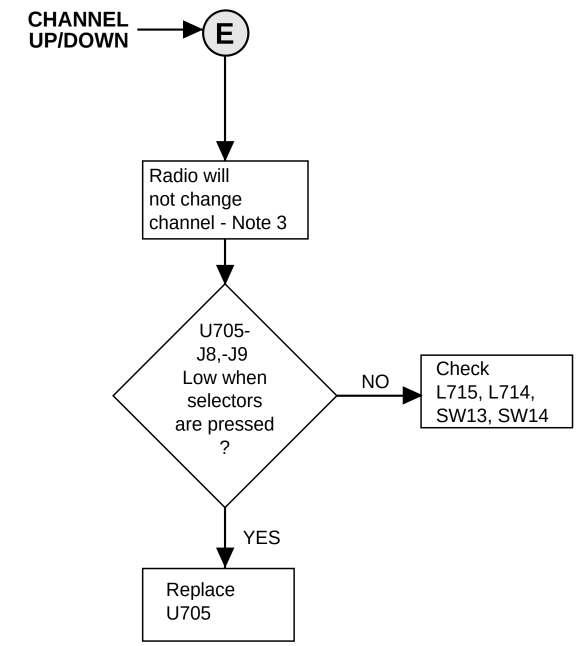
Figure 11-14. Troubleshooting Flow Chart Controller



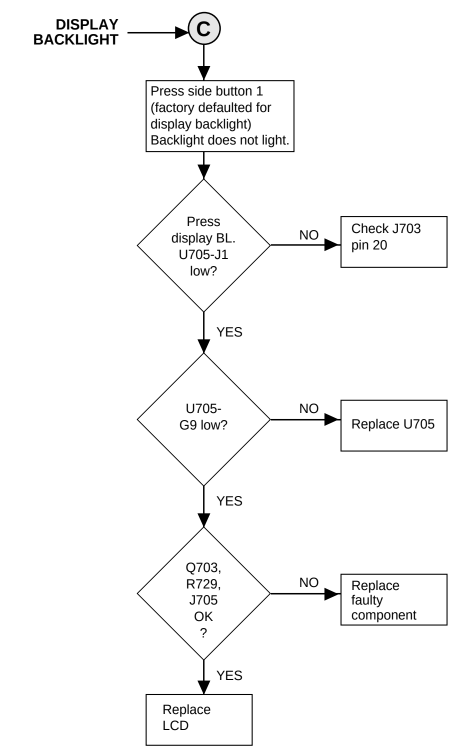
Part of MAEPF-23513-O



Part of MAEPF-23513-O

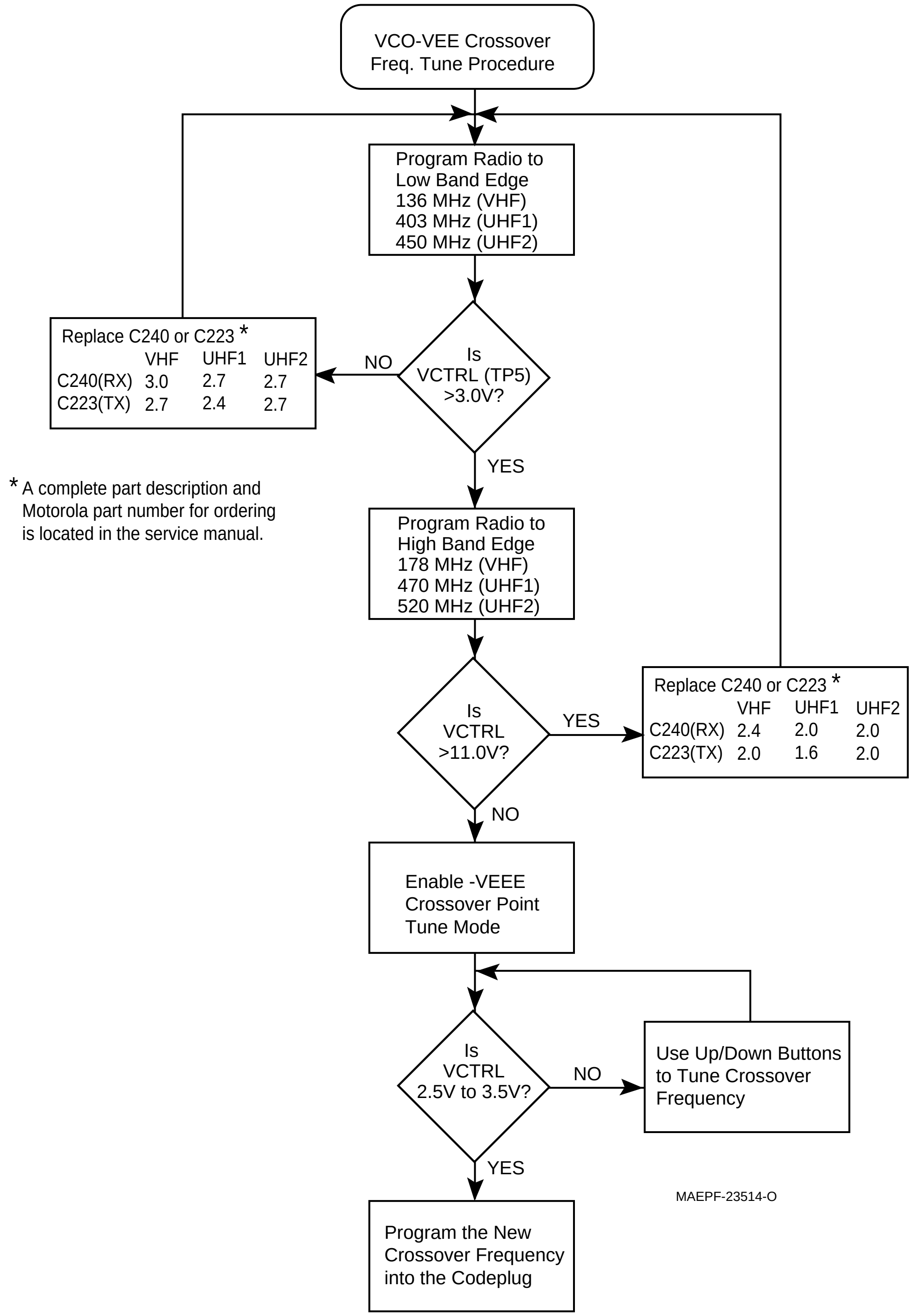


Part of MAEPF-23513-O



Part of MAEPF-23513-O

Figure 11-15. Troubleshooting Flow Chart Controller Additions



MAEPF-23513-O

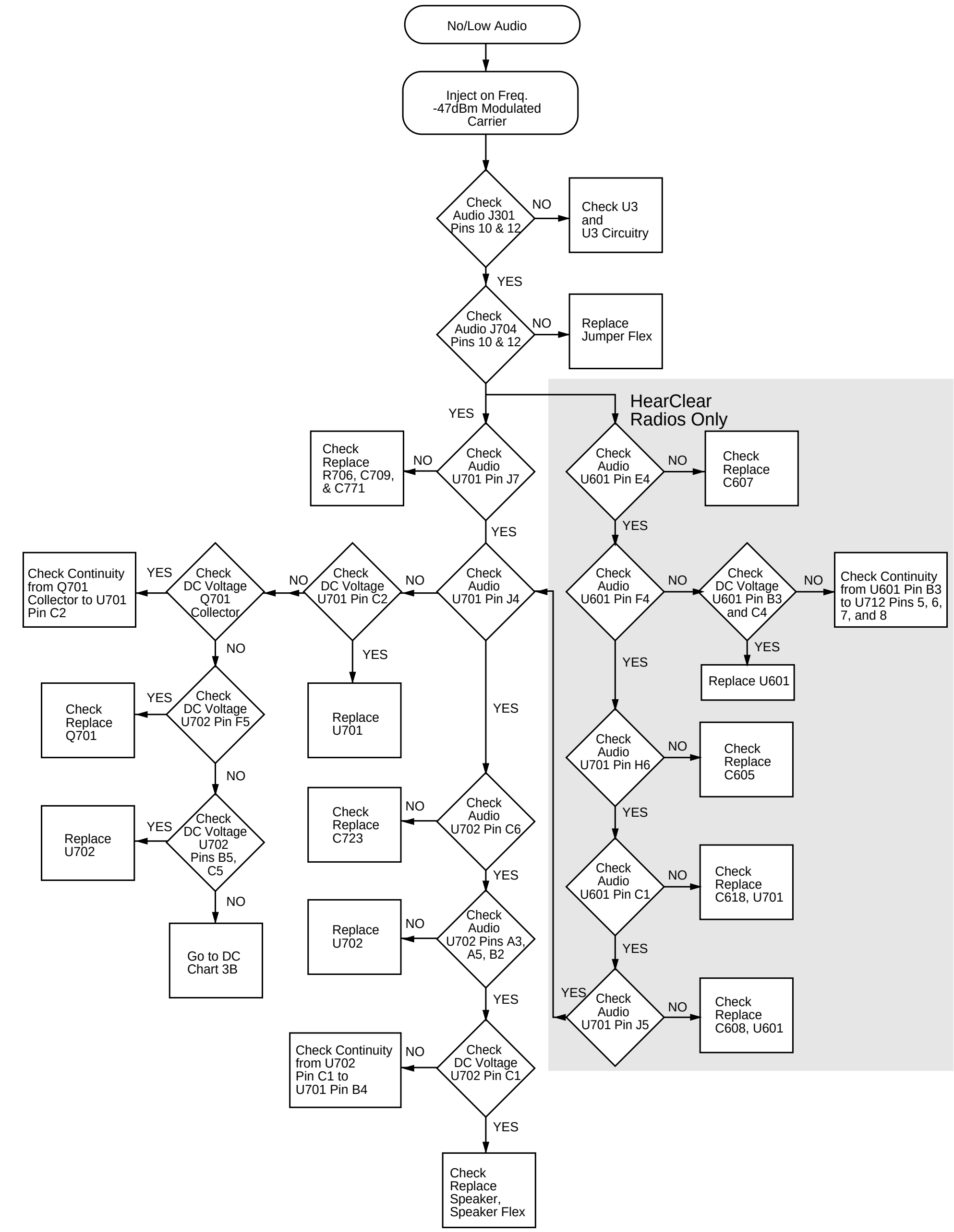


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Figure 11-16. Troubleshooting Flow Chart VHF/UHF Only VCo Crossover Frequency Tune

Figure 11-17. Troubleshooting Flow Chart 800/900MHz No Receiver Audio