ARRL Laboratory
Expanded Test-Result Report
Ten-Tec Argonaut V

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Model Information:
Argonaut V   Serial #: 08C10452
QST "Product Review" April, 2003

Manufacturer:
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Contents:

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Introduction

This document summarizes the extensive battery of tests performed by the ARRL Laboratory for each unit that is featured in *QST* "Product Review." For all tests, there is a discussion of the test and test method used in ARRL Laboratory testing. For most tests, critical conditions are listed to enable other engineers to duplicate our methods. For some of the tests, a block diagram of the test setup is included. The ARRL Laboratory has a document, the *ARRL Laboratory Test Procedures Manual,* that explains our specific test methods in detail. While this is not available as a regular ARRL publication, it may be downloaded from our web page.

Most of the tests used in ARRL product testing are derived from recognized standards and test methods. Other tests were developed by the ARRL Lab. The ARRL Laboratory test equipment is calibrated annually, with traceability to National Institute of Standards and Technology (NIST).

The units being tested are operated as specified by the equipment manufacturer. Equipment that can be operated from 13.8 volts (nominal) is also tested for function, output power and frequency accuracy at the minimum specified voltage, or 11.5 volts if not specified. Also, units that are capable of mobile or portable operation are tested at their rated temperature range, or at –10 to +60 degrees Celsius in a commercial temperature chamber.

ARRL "Product Review" testing usually represents a sample of only one unit, although we sometimes obtain an extra sample or two for comparison purposes. This is not necessarily representative of all units of the same model number. It is not uncommon that some parameters will vary significantly from unit to unit. The ARRL Laboratory and Product Review editor work with manufacturers to resolve any deviation from specifications or other problems encountered in the review process. These problems are documented in the Product Review.

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Transmitter Output Power

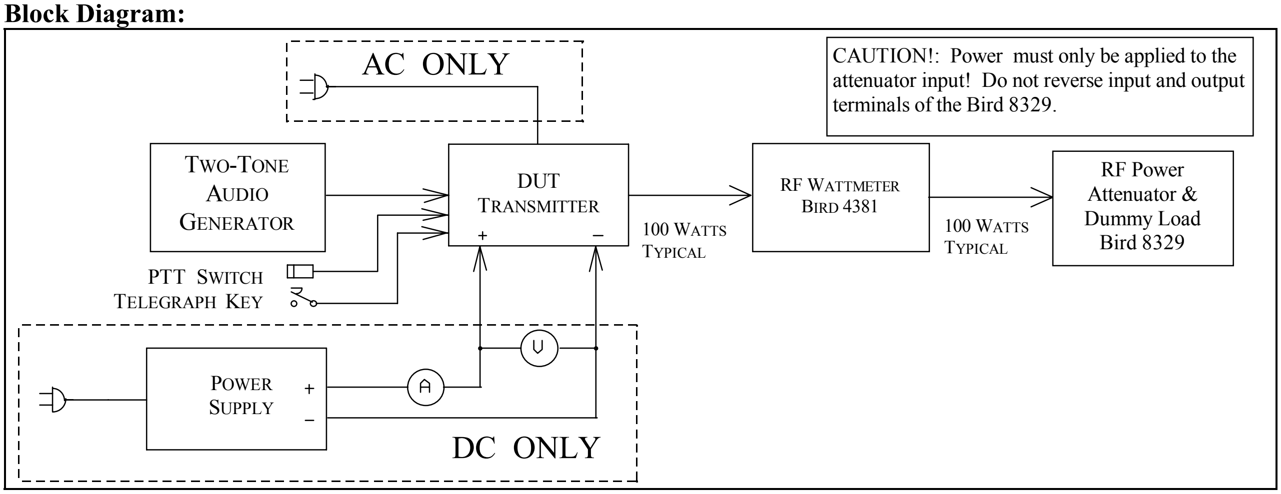
Test description: One of the first things an amateur wants to know about a transmitter or transceiver is its RF output power. The ARRL Lab measures the CW output power for every band on which a transmitter can operate. The equipment is also tested on one or more bands for any other mode of operation for which the transmitter is capable. Another purpose of this test is to measure the dc current consumption at the manufacturer's specified dc-supply voltage, if applicable.

Many transmitters are de-rated from maximum output power on full-carrier AM and FM modes. In most cases, a 100-watt CW/SSB transmitter may be rated at 25 watts carrier power on AM. The radio may actually deliver 100 watts PEP in AM or FM but is not specified to deliver that power level for any period of time.

In almost all cases, the linearity of a transmitter decreases as output power increases. A transmitter rated at 100 watts PEP on single sideband may actually be able to deliver more power, but as the power is increased beyond the rated RF output power, adjacent channel splatter (IMD) usually increases dramatically.

Key Test Conditions:
Termination: 50 ohms resistive, or as specified by the manufacturer.

Block Diagram:



Transmitter Output Power Results

Frequency Band	Mode	Unit Minimum Power (W)	Measured Minimum Power (W)	Unit Maximum Power (W)	Measured Maximum Power (W)	Notes
1.8 MHz	CW	< 1	< 1	~17W	18.9	
3.5 MHz	CW	< 1	< 1	~17W	18.4	
7.0 MHz	CW	< 1	< 1	~17W	18.4	
10.1 MHz	CW	< 1	< 1	~17W	17.5	
14 MHz	CW	< 1	< 1	~17W	17.3	
14 MHz	USB	< 1	< 1	~17W	19.0	
18 MHz	CW	< 1	< 1	~17W	18.0	
21 MHz	CW	< 1	< 1	~17W	18.3	
24 MHz	CW	< 1	< 1	~17W	16.3	
28 MHz	CW	< 1	< 1	~17W	16.9	
28 MHz	FM	< 1	< 1	~17W	17.1	

Note: a second unit tested had slightly higher output power on many of the bands (ranging 16.9-19.4W)

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Current Consumption

(DC-powered units only)

Test Description: Current consumption can be important to the success of mobile and portable operation. The ARRL Lab tests the current consumption of all equipment that can be operated from a battery or 12-14 v dc source. The equipment is tested in transmit at maximum output power. On receive, it is tested at maximum volume, with no input signal, using the receiver's broadband noise. Any display lights are turned on to maximum brightness, if applicable. This test is not performed on equipment that can be powered only from the ac mains.

Current Consumption:

Voltage	Transmit Current	Output Power	Receive Current	Lights?	Notes
13.8 V	7.5 A	18.0 W	1.1 A	ON	1, 2

1. Ten-Tec specifies "500 ma typical" for receive current, but the ARRL Lab measured about 1A at minimum volume.
2. Transmit current consumption on a second unit was 6.5 A at max output.

Transmit Frequency Range

Test Description: Many transmitters can operate outside the amateur bands, either intentionally (to accommodate MARS operation, for example) or unintentionally as the result of the design and internal software. The ARRL Lab tests the transmit frequency range to determine the range of frequencies, on which the transmitter operates. The key test conditions are rated power and nominal supply voltages. Frequencies are as indicated on the transmitter frequency indicator or display. Although most modern synthesized transmitters are capable of operation outside the ham bands, spectral purity is not always legal outside the bands, so caution must be used. In addition, most other radio services require that transmitting equipment be type accepted for that service. Amateur equipment is not legal for use on other than amateur and MARS frequencies.

Test Results:

Frequency	Low-Frequency Limit	High-Frequency Limit	Notes
160 M	1.795 440 MHz	2.006 820 MHz	
80 M	3.495 440 MHz	4.006 820 MHz	
40 M	6.995 440 MHz	7.306 820 MHz	
30 M	10.095 440 MHz	10.156 820 MHz	
20 M	13.995 440 MHz	14.006 820 MHz	
17 M	18.062 940 MHz	18.176 820 MHz	
15 M	20.995 440 MHz	21.456 820 MHz	
12 M	24.885 440 MHz	24.996 820 MHz	
10 M	27.995 440 MHz	29.706 820 MHz	

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CW Transmit Frequency Accuracy

Test Description: Most modern amateur equipment is surprisingly accurate in frequency. It is not uncommon to find equipment operating within a few Hz of the frequency indicated on the frequency display. However, some units, notably "analog" units, not using a phase-lock loop in the VFO design, can be off by a considerable amount. This test measures the output frequency. Unit is operated into a 50-ohm resistive load at nominal temperature and supply voltage.

Test Results:

Unit Frequency	Supply Voltage	Temperature	Measured Frequency Full Output Power	Notes
14.000 00 MHz	13.8 V	25 C	14.000.001 MHz	1

1. Review unit was equipped with the TCXO option.

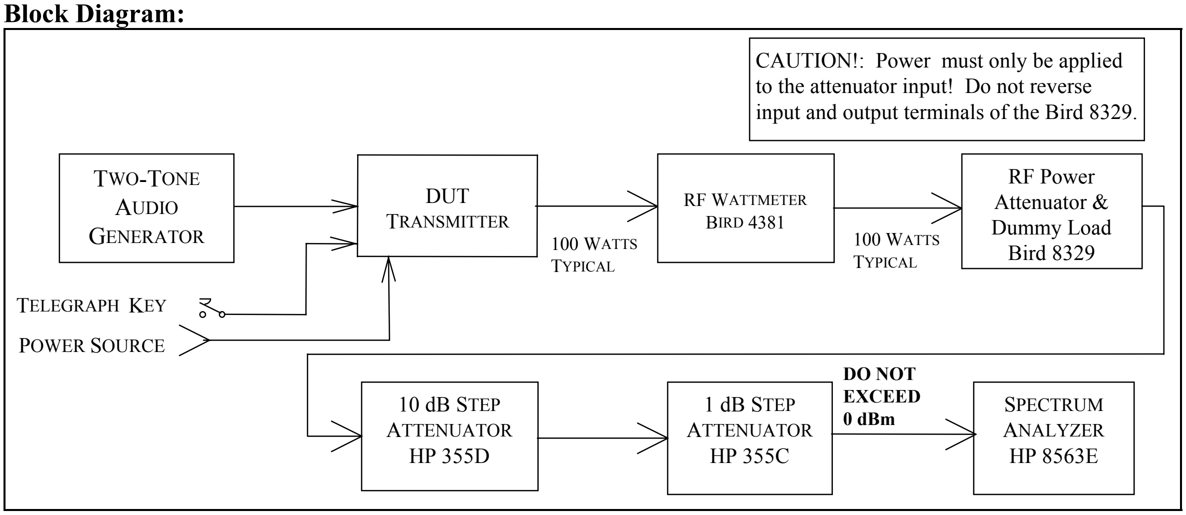
Spectral Purity

Test Description: All transmitters emit some signals outside their assigned frequency or frequency range. These signals are known as spurious emissions or "spurs." Part 97 of the FCC rules and regulations specify the amount of spurs that can be produced by a transmitter operating in the Amateur Radio Service. The ARRL Laboratory uses a spectrum analyzer to measure the spurious emission on each band. The transmitter is tested across the entire band and the worst-case spectral purity in each case is recorded.

The graphs and tables indicate the relative level of spurs from the transmitter. The lower that level, expressed in dB relative to the output carrier, the better the transmitter is. So a transmitter whose spurious emissions are –60 dBc is spectrally cleaner than is one whose spurious emissions are –40 dBc.

Key Test Conditions:
Unit is operated at nominal supply voltage and temperature.
Output power is adjusted to full power on each amateur band.
A second measurement is taken at minimum power to ensure that the spectral output is still legal at low power.

Block Diagram:



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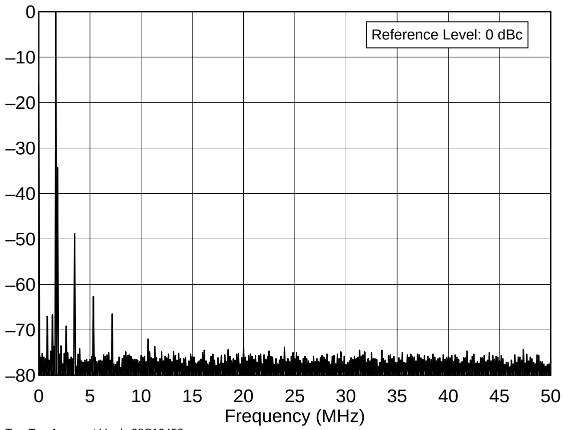
Spectral-Purity Graphs



Ten-Tec Argonaut V, s/n 08C10452
1.8 MHz Band, Spectral Purity, 20 W
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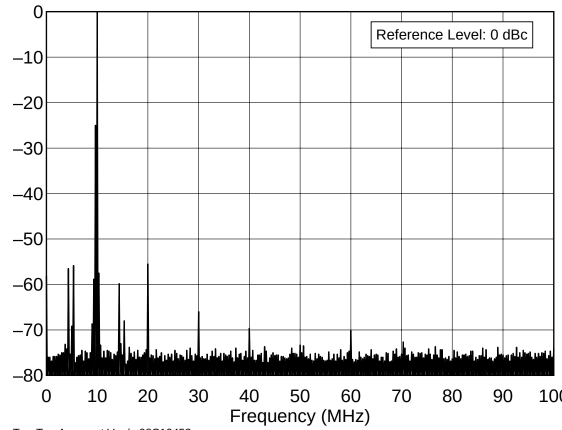

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10.1 MHz Band, Spectral Purity, 20 W
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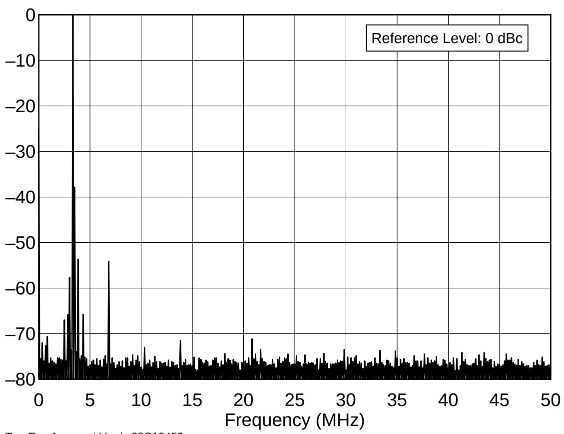

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3.5 MHz Band, Spectral Purity, 20 W
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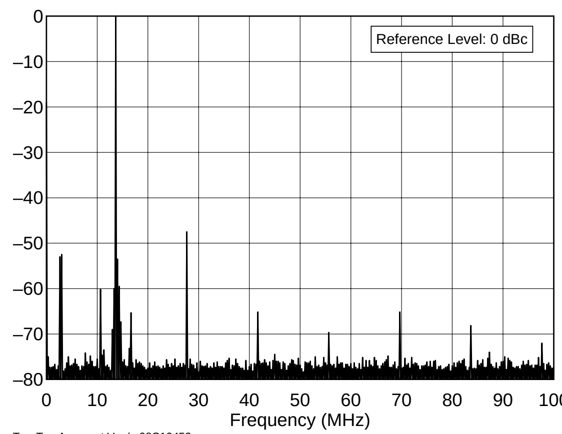

Ten-Tec Argonaut V, s/n 08C10452
14.0 MHz Band, Spectral Purity, 20 W
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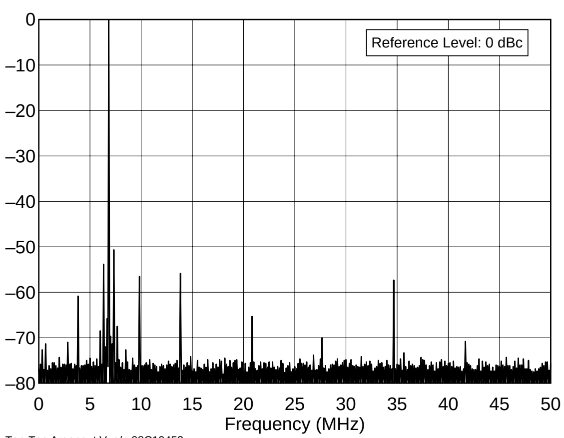

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7.0 MHz Band, Spectral Purity, 20 W
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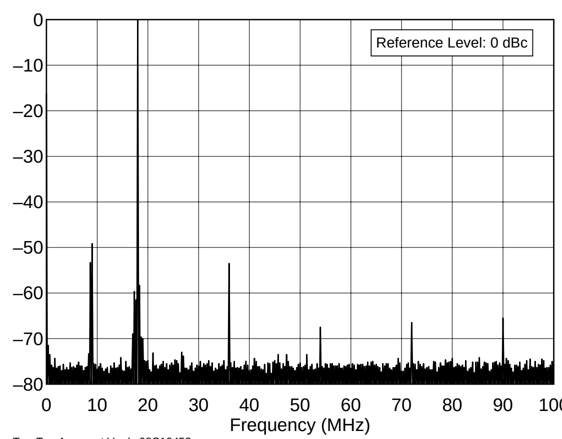

Ten-Tec Argonaut V, s/n 08C10452
18.1 MHz Band, Spectral Purity, 20 W
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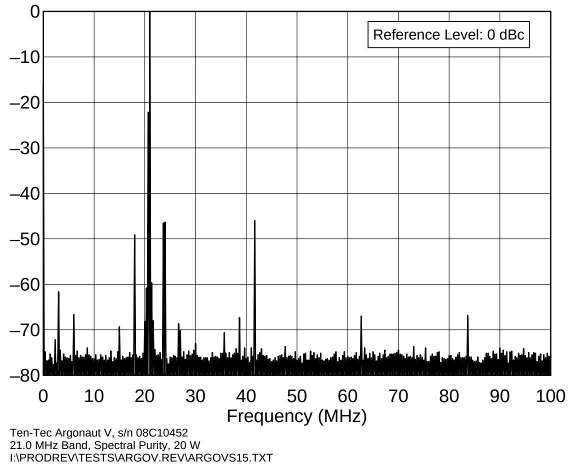

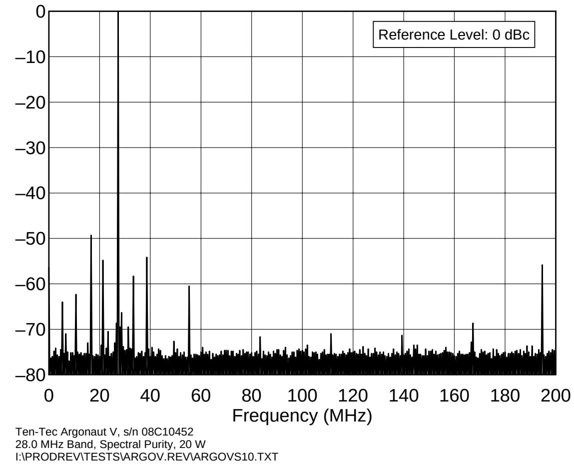

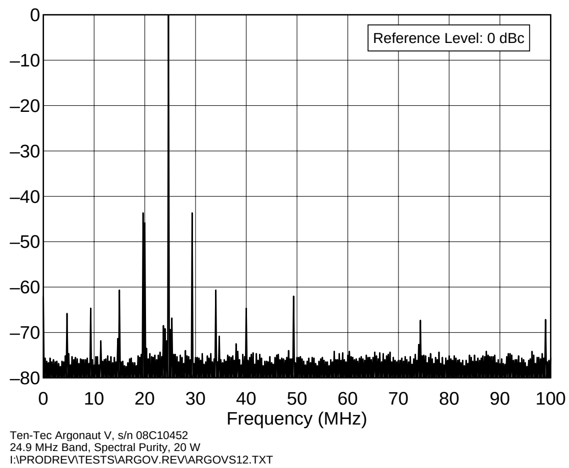

Transmit Two-Tone IMD

Test Description: Investigating the sidebands from a modulated transmitter requires a narrow-band spectrum analysis. In this test, a two-tone audio signal (frequencies of 700 and 1900 Hz) is used to modulate the transmitter. The display shows the two tones plus some of the intermodulation distortion (IMD) products produced by the SSB transmitter. These frequencies were selected to be within the audio passband of the typical transmitter, resulting in a meaningful display of transmitter IMD. The level shown is dB relative to Peak Envelope Power (PEP). The lower the intermodulation products, the better the transmitter. In general, it is the products that are farthest removed from the two tones (typically > 3 kHz away) that cause the most problems. These can cause splatter up and down the band from strong signals.

Key Test Conditions:
Transmitter operated at rated power. Audio tone and mic gain level adjusted for best performance. Level to the analyzer is –10 dBm maximum. Resolution bandwidth, 10 Hz

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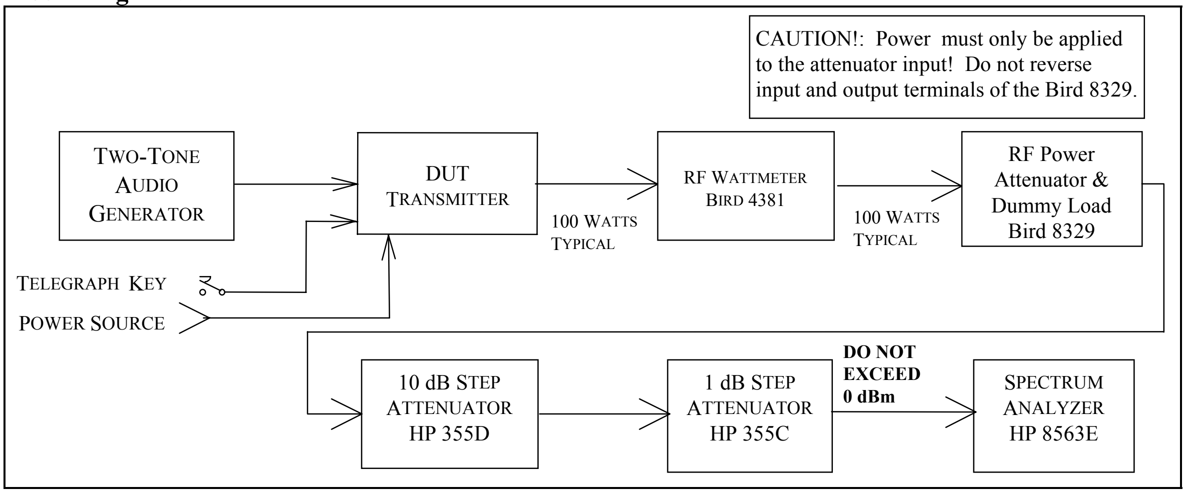
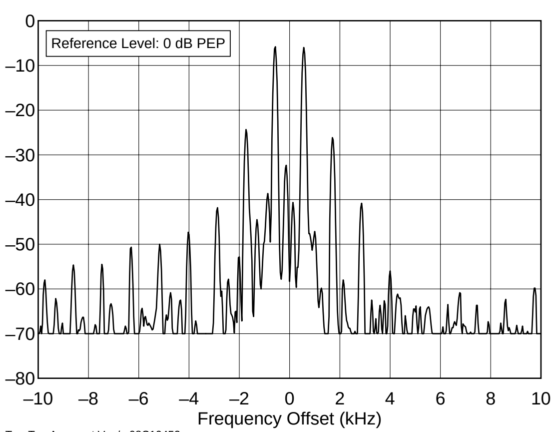
Block Diagram:



Test Result Summary:

Frequency	Worst-case 3rd-order dB PEP	Worst-case 5th-order dB PEP	Notes
1.85 MHz	–25	–40	
3.9 MHz	–30	–47	
7.25 MHz	–32	–52	
10.12 MHz	–29	–55	
14.25 MHz	–29	–43	
18.12 MHz	–30	–43	
21.25 MHz	–30	–48	
24.95 MHz	–25	–43	
28.35 MHz	–27	–46	

Transmit IMD Graphs



Ten-Tec Argonaut V, s/n 08C10452
1.850 MHz, Transmit IMD, 20 W
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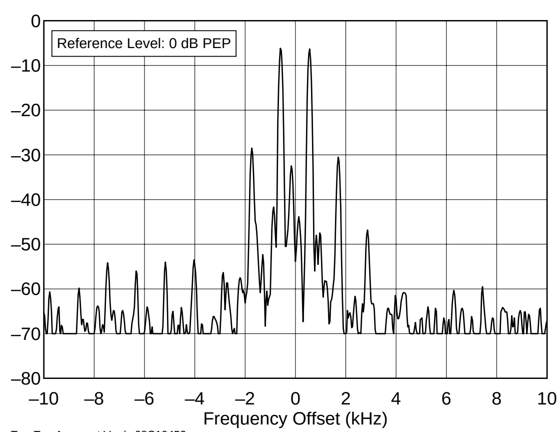

Ten-Tec Argonaut V, s/n 08C10452
3.900 MHz, Transmit IMD, 20 W
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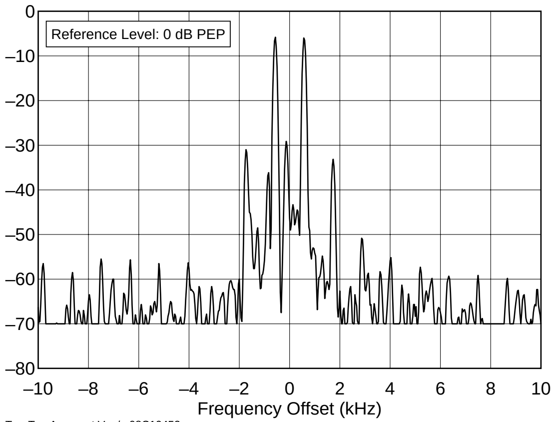

Ten-Tec Argonaut V, s/n 08C10452
7.250 MHz, Transmit IMD, 20 W
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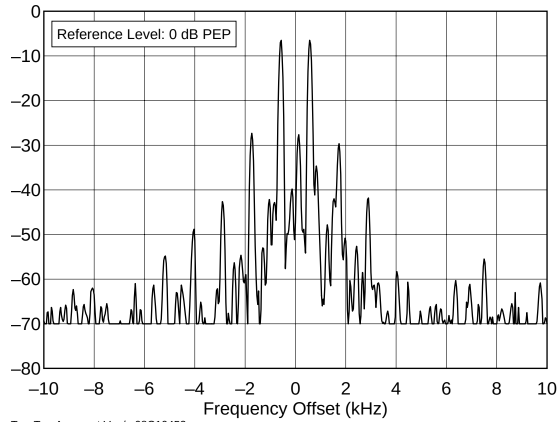

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18.120 MHz, Transmit IMD, 20 W
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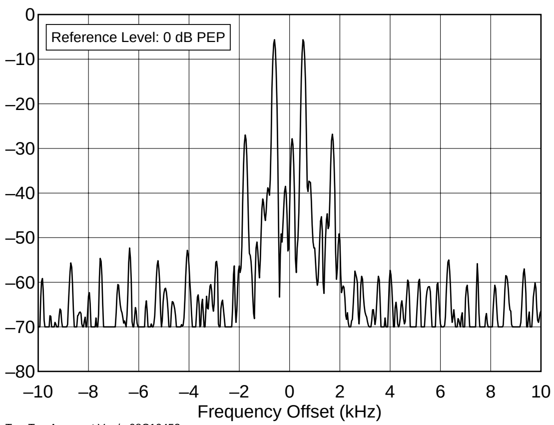

Ten-Tec Argonaut V, s/n 08C10452
10.120 MHz, Transmit IMD, 20 W
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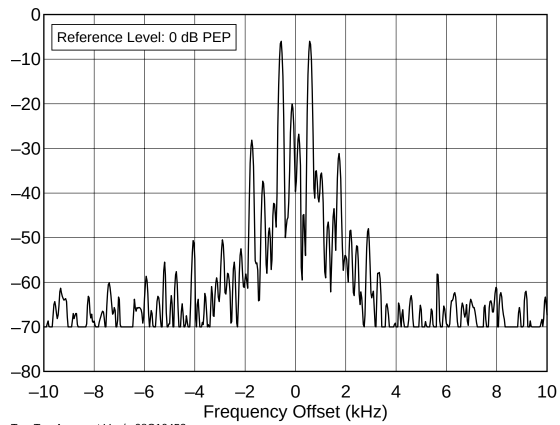

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21.250 MHz, Transmit IMD, 20 W
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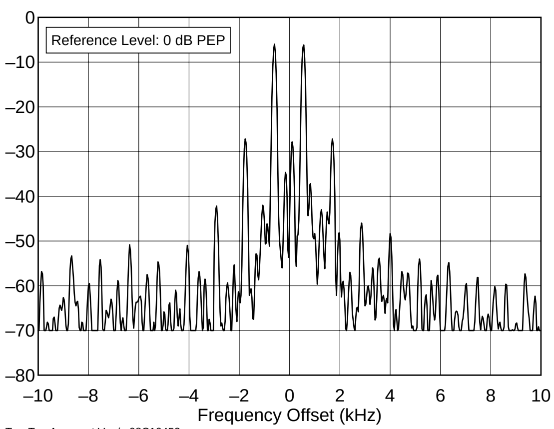

Ten-Tec Argonaut V, s/n 08C10452
14.250 MHz, Transmit IMD, 20 W
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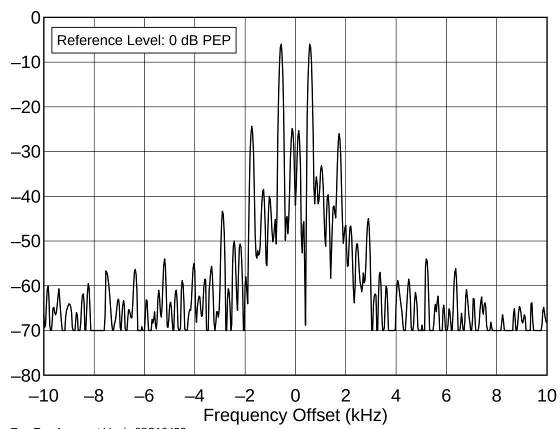

Ten-Tec Argonaut V, s/n 08C10452
24.950 MHz, Transmit IMD, 20 W
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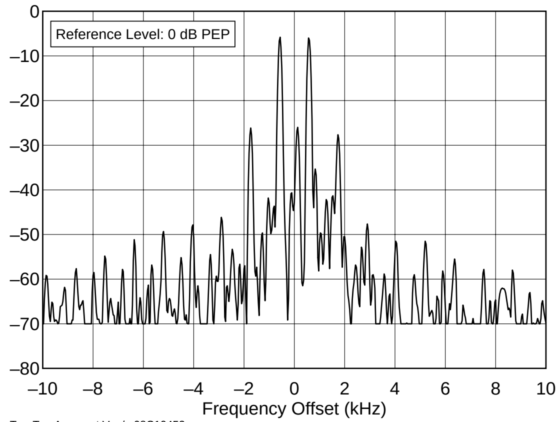

Ten-Tec Argonaut V, s/n 08C10452
28.350 MHz, Transmit IMD, 20 W
I:\PRODREV\TESTS\ARGOV.REV\ARGOVI10.TXT

SSB Carrier and Unwanted Sideband Suppression

Test Description: The purpose of this test is to determine the level of carrier and unwanted sideband suppression relative to Peak Envelope Power (PEP). The transmitter output is observed on the spectrum analyzer and the unwanted components are compared to the desired sideband. The greater the amount of suppression, the better the transmitter. For example, opposite sideband suppression of 60 dB is better than suppression of 50 dB.

Test Results:

Frequency	Carrier Suppression	Opposite Sideband Suppression	Notes
14.2 MHz USB	–62 dB PEP	–70 dB PEP	
14.2 MHz LSB	–69 dB PEP	–73 dB PEP	

CW Keying Waveforms and Sidebands

Test Description: The purpose of this test is to determine the shape of the transmitter's RF output envelope in the CW mode, and to measure the sidebands generated by the transmitter. If the transmitter under test has several CW modes, (VOX, QSK) these are also tested. A picture of the oscilloscope screen is taken of the results. The first and second dits are shown in all modes.

If the rise or fall times become too short, the transmitter may generate key clicks. Most click-free transmitters have rise and fall times between 1 and 5 ms. However, key clicks are most often generated by sudden transitions in the keying envelope (e.g., "square corners"), so a short rise or fall time is not a guarantee of clicks.

The absolute values of the on delay and off delay are not critical, but it is important that they be approximately the same so that CW weighting will not be affected. Some transmitters used in the VOX mode exhibit a first dit that is shorter than subsequent dits. Other transmitters can show significant shortening of all dits when used in the QSK mode. The latter will cause keying to sound choppy.

This test also measures the sidebands generated by the transceiver on high speed CW. This is an indication of the degree to which a transmitter may exhibit 'key clicks'. The transmitter is keyed at 60-wpm by an external circuit. The sidebands are measured on the spectrum analyzer using a resolution bandwidth of 10 Hz, and a long sweep time (30 seconds) so the worst-case spectrum is captured. Note that in a receiver with a bandwidth of 500 Hz, the sidebands would be heard at a level 17 dB higher than the graph indicates (10*LOG(500/10)=17).

Key Test Conditions:
The transmitter is operated at room temperature at rated output power into a 50-ohm resistive load. The power supply voltage is nominal. Note that the keying rate used on this transceiver was 40 WPM instead of the ARRL Lab standard of 60 WPM. See Review text for details.

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Figure 1 - First and second dits (horizontal scale is 10 ms/division).

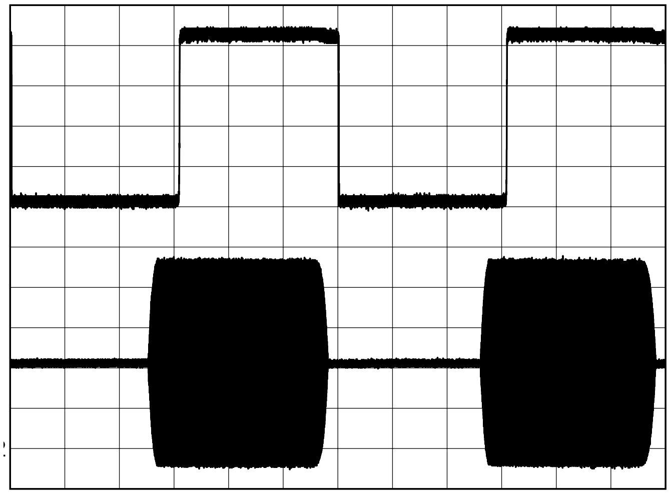
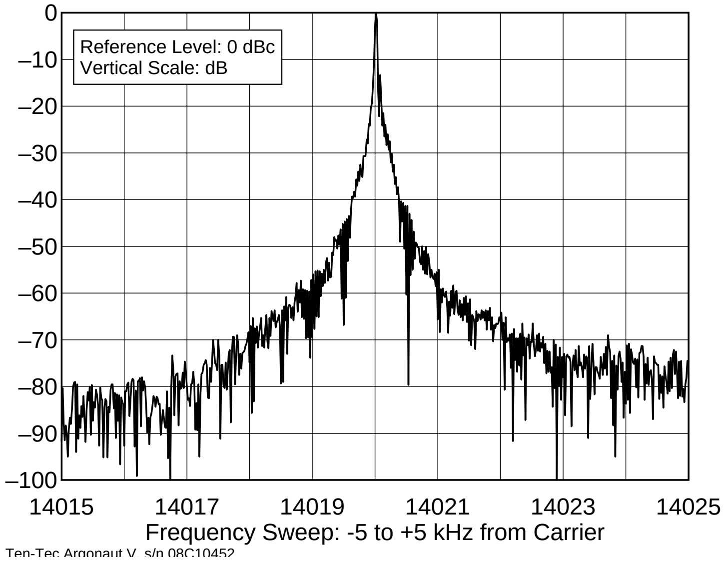


Figure 2 - Keying sidebands, 10 Hz bandwidth



CW Keyer Speed Range

Test Description: This test measures the speed of the internal keyer on transmitters so equipped. The keyer is tests at minimum, midrange and maximum speeds and the time from dit to dit is measured using an oscilloscope and used to calculate the speed using the "Paris" method of code speed calculation. (In the Paris method, the word "Paris" is used as the standard word to calculate words per minute.)

Test Results:

Min WPM	Max WPM	Default WPM	Notes
5.0 wpm	44 wpm	13 wpm	1

Notes:
1. Specified keyer range = 5 to 50 wpm.

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Keyer Sidetone Frequency

Test Description: This test measures the audio frequency of the keyer sidetone.

Test Result:

Default pitch	Minimum	Maximum	Notes
701 Hz	402 Hz	999 Hz	

Notes:

Transmit/Receive Turnaround Time

Test Description: The purpose of the Transmit/Receive turnaround test is to measure the delay required to switch from transmit to receive on a transceiver.

Test Results:

Frequency	Conditions	T/R Delay	Notes
14.2 MHz	50% audio	24 ms	1

Notes:
1. T/R delay less than or equal to 35 ms is suitable for use on AMTOR.

Transmit Delay Time

Test Description: The purpose of the Transmit Delay test is to measure the time between PTT closure and 50% RF output. It is measured on SSB, modulated with a single tone and on FM, unmodulated.

Test Results:

Frequency	Mode	Delay	Notes
14.2 MHz	SSB	25 ms	
29.2 MHz	FM	25 ms	

Transmit Composite Noise

Test Description: The purpose of this test is to observe and measure the phase and amplitude noise of the local oscillator, as well as any spurious signals generated by the transmitter under test. Since phase noise is the primary noise component in any well-designed transmitter, it can be assumed, therefore, that almost all the noise observed during this test is phase noise. This measurement is accomplished by converting the output of the transmitter down to a frequency about 10 or 20 Hz above baseband. A mixer and a signal generator used as a local oscillator are used to perform this conversion. Filters remove the 0 Hz component as well as the unwanted heterodyne components. The remaining noise and spurious signals are then observed on the spectrum analyzer. The lower the noise as seen on the plot, the better the transmitter.

Key Test Conditions:
Transmitter operated at rated output power into a 50-ohm resistive load.
Transmitter operated at room temperature.
Frequencies from 2 to 22 kHz from the carrier are measured.
Ten sweeps are averaged on the spectrum analyzer to reduce noise.

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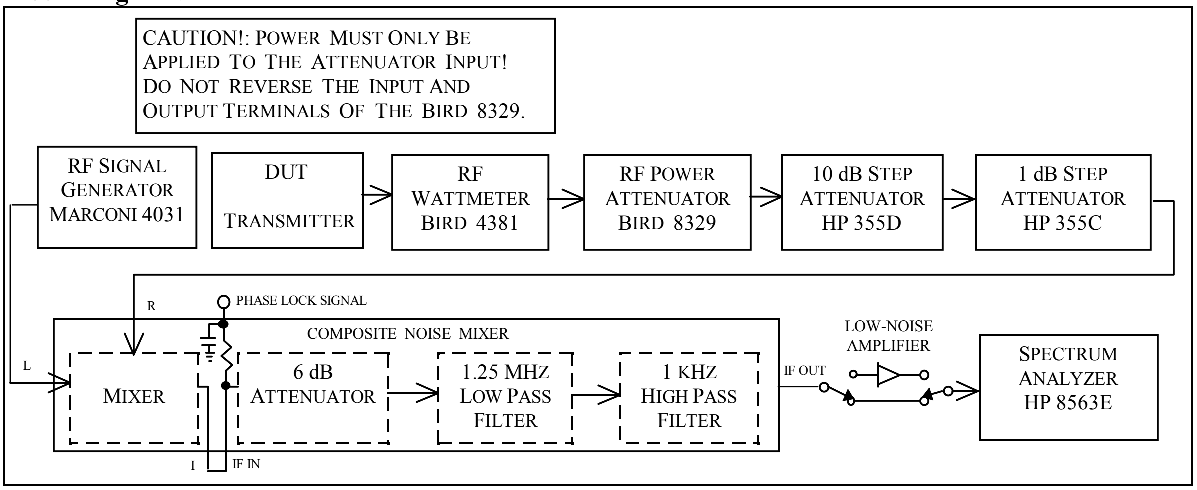
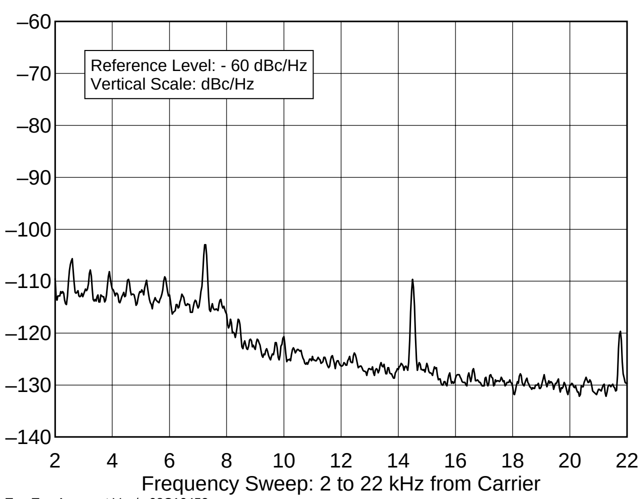
Block Diagram:



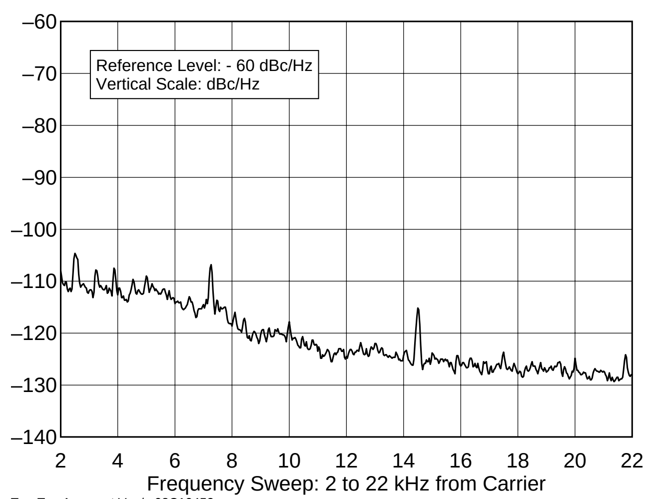
Test Results:

Frequency	2 kHz offset (dBc/Hz)	20 kHz offset (dBc/Hz)	Notes
3.520 MHz	–113	–130	
14.02 MHz	–110	–127	

Transmit Composite Noise Graphs



Ten-Tec Argonaut V, s/n 08C10452
3.520 MHz, Phase Noise, 20 W
I:\PRODREV\TESTS\ARGOV.REV\ARGOVP80.TXT



Ten-Tec Argonaut V, s/n 08C10452
14.020 MHz, Phase Noise, 20 W
I:\PRODREV\TESTS\ARGOV.REV\ARGOVP20.TXT

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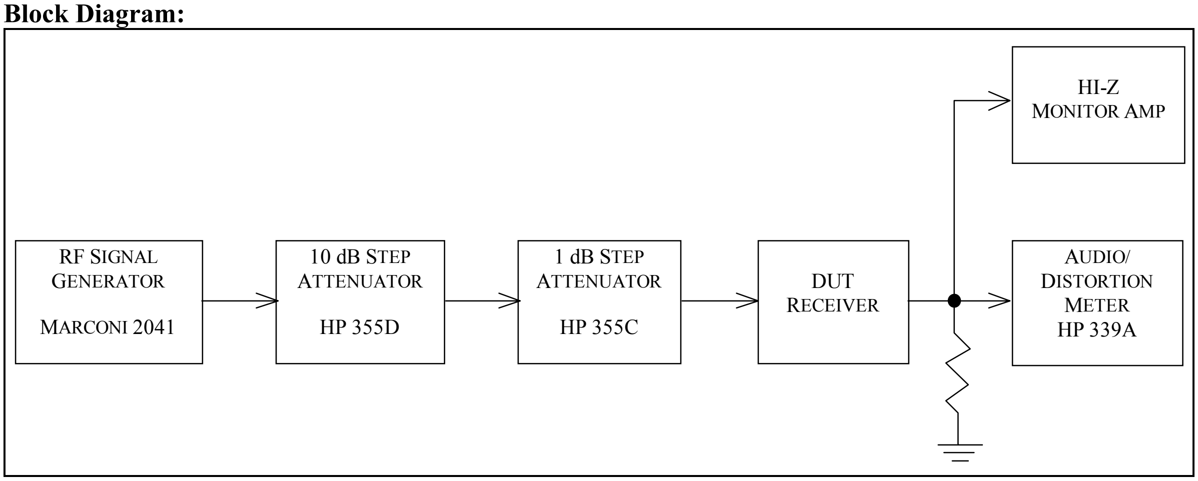
Receiver Noise Floor

(Minimum Discernible Signal)

Test Description: The noise floor of a receiver is the level of input signal that gives a desired audio output level that is equal to the noise output level. This is sometimes called "minimum discernible signal" (MDS), although a skilled operator can detect a signal up to 10 dB or so below the noise floor. Most modern receivers have a noise floor within a few dB of "perfect." A perfect receiver would hear only the noise of a resistor at room temperature. However, especially for HF receiving systems, the system noise is rarely determined by the receiver. In most cases, external noise is many dB higher than the receiver's internal noise. In this case, it is the external factors that determine the system noise performance. Making the receiver more sensitive will only allow it to hear more noise. It will also be more prone to overload. In many cases, especially in the lower HF bands, receiver performance can be improved by sacrificing unneeded sensitivity by placing an attenuator in front of the receiver. The more negative the sensitivity number expressed in dBm, or the smaller the number expressed in voltage, the better the receiver.

Key Test Conditions:
Source impedance (generator) of 50-ohms. Receiver audio output to be terminated with specified impedance.
Receiver is tested using 500 Hz bandwidth, or closest available bandwidth to 500 Hz.

Block Diagram:



Noise Floor:

Frequency	MDS (dBm)	Notes
1.02 MHz	–120.8	
1.82 MHz	–132.5	
3.52 MHz	–132.5	
7.02 MHz	–133.3	
10.12 MHz	–133.3	
14.02 MHz	–131.7	
18.088 MHz	–130.2	
21.02 MHz	–130.8	
24.91 MHz	–129.4	
28.02 MHz	–129.4	

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Receive Frequency Range

Test Description: This test measures the tuning range of the receiver. The range expressed is the range over which the receiver can be tuned. Most receivers exhibit some degradation of sensitivity near the limits of their tuning range. In cases where this degradation renders the receiver unusable, we report both the actual and useful tuning range.

Test Results:

Minimum Frequency	MDS @ Min. Frequency	Maximum Frequency	MDS @ Max. Frequency	Notes
500 kHz	–110.6 dBm	30 MHz	–129.4 dBm	

AM Sensitivity

Test Description: The purpose of the AM receive Sensitivity Test is to determine the level of an AM signal, 30% modulated at 1 kHz, that results in a tone 10 dB above the noise level (MDS) of the receiver. Two frequencies, 1.020 MHz and 3.800 MHz are used for this test. The more negative the number, expressed in dBm, or the smaller the number expressed in voltage, the better the sensitivity.

Test Results:

Frequency	10 dB S/N	Frequency	10 dB S/N	Notes
1.02 MHz	7.15 µV	3.9 MHz	1.24 µV	

FM SINAD

Test Description: The purpose of the FM SINAD and Quieting Test is to determine the 12 dB SINAD value. SINAD is an acronym for "SIgnal plus Noise And Distortion" and is a measure of signal quality. The exact expression for SINAD is:

$$\text{SINAD} = \frac{\text{Signal + Noise + Distortion}}{\text{Noise + Distortion}} \quad \text{(expressed in dB)}$$

If we consider distortion to be merely another form of noise, (distortion, like noise, is something unwanted added to the signal), we can further reduce the equation for SINAD to:

$$\text{SINAD} = \frac{\text{Signal + Noise}}{\text{Noise}} \quad \text{(expressed in dB)}$$

If we now consider a practical circuit in which the signal is much greater than the noise, the value of the SIGNAL + NOISE can be approximated by the level of the SIGNAL alone. The SINAD equation then becomes the signal to noise ratio. The approximation now becomes:

$$\text{SINAD} = \frac{\text{Signal}}{\text{Noise}} \quad \text{(expressed in dB)}$$

For the 25% level of distortion, the SINAD value can be calculated as follows:

$$\text{SINAD} = 20 \log (1/25\%) = 20 \log 4 = 12 \text{ dB}$$

The more negative the number, expressed in dBm, or the smaller the number, expressed as voltage, the better the sensitivity.

SINAD Test Results:

Frequency	12 dB SINAD	Notes
29.0 MHz	1.27 µV	

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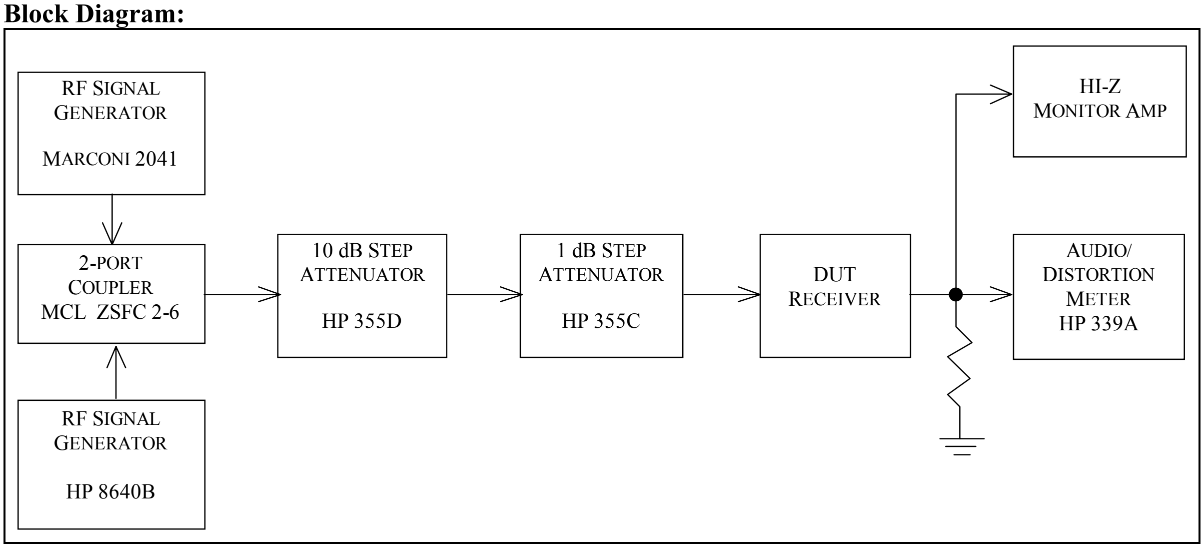
Blocking Dynamic Range

Test Description: Dynamic range is a measurement of a receiver's ability to function well on one frequency in the presence of one or more unwanted signals on other frequency. It is essentially a measurement of the difference between a receiver's noise floor and the loudest off-channel signal that can be accommodated without measurable degradation of the receiver's response to a relatively weak signal to which it is tuned. This difference is usually expressed in dB. Thus, a receiver with a dynamic range of 100 dB would be able to tolerate an off-channel signal 100 dB stronger than the receiver's noise floor.

In the case of Blocking Dynamic Range (BDR), the degradation criterion is receiver desensitization. BDR is the difference, in dB, between the noise floor and an off-channel signal that causes 1 dB of gain compression in the receiver (e.g., desensitization). BDR is calculated by subtracting the noise floor from the level of the undesired signal. The greater the dynamic range, expressed in dB, the better the receiver performance. It is usual for the dynamic range to vary with frequency spacing.

Key Test Conditions:
AGC is normally turned off; the receiver is operated in its linear region. The desired signal level is set to 10 dB below the 1-dB compression point, or 20 dB above the noise floor in receivers in which the AGC cannot be disabled. The receiver bandwidth is set as close as possible to 500 Hz.

Block Diagram:



Blocking Dynamic Range Test Result:

Band	Spacing	BDR dB	Notes
1.82 MHz	50 kHz	120.5 *	
3.52 MHz	100 kHz	123.5	
3.52 MHz	50 kHz	119.5	
3.52 MHz	20 kHz	111.5	
3.52 MHz	5 kHz	66.5	
7.02 MHz	50 kHz	121.5 *	
14.02 MHz	100 kHz	122.7 *	1
14.02 MHz	50 kHz	116.6 *	
14.02 MHz	20 kHz	118.0	
14.02 MHz	5 kHz	66.8	
21.02 MHz	50 kHz	117.8 *	
28.02 MHz	50 kHz	115.4 *	

* Measurement was noise limited at the value indicated.
1. Testing on a second unit showed similar results.

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Two-Tone 3rd-Order Dynamic Range

Test Description: Two-tone InterModulation Distortion Dynamic Range (IMD DR) measures the impact of the intermodulation of two strong (undesired) signals within a receiver. IMD is the production of spurious responses resulting from the mixing of these undesired signals within the receiver's RF stages. Two-Tone IMD DR is the difference, in dB, between the noise floor and the strength of two equal off-channel signals that produce undesired products equal to the noise floor.

The strongest of these undesired products are known as the 3rd order products, so named because of the mathematical relationship they have to the original frequencies. To perform a 3rd Order test, two signals of equal amplitude and spaced a given distance (such as 20 kHz) apart, are injected into the input of the receiver. If we call these frequencies f_1 and f_2, the third-order products will appear at frequencies of $(2f_1-f_2)$ and $(2f_2-f_1)$.

Key Test Conditions: Sufficient attenuation and isolation must exist between the two signal generators. The two-port coupler must be terminated in a load that exhibits a 20-dB or better return loss at the coupler output. The receiver is set as close as possible to a 500 Hz bandwidth.

TT IMD DR Block Diagram (see BDR diagram)

Two-Tone IMD DR Test Result Summary:

Band	Spacing	IMD DR	Notes
1.82 MHz	50 kHz	93.5 dB	
3.52 MHz	100 kHz	92.5 dB	
3.52 MHz	50 kHz	92.5 dB	
3.52 MHz	20 kHz	84.5 dB	
3.52 MHz	5 kHz	60.5 dB	
7.02 MHz	50 kHz	94.3 dB	
14.02 MHz	100 kHz	93.7 dB	1
14.02 MHz	50 kHz	92.7 dB	
14.02 MHz	20 kHz	84.7 dB	
14.02 MHz	5 kHz	61.7 dB	
21.02 MHz	50 kHz	88.8 dB	
28.02 MHz	50 kHz	84.4 dB	

1. Testing on a second unit showed similar results.

Third-Order Intercept

Test Description: Third-order intercept (IP3) is not actually a separate test, but is part of the IMD Dynamic Range test. The third-order response of the receiver can be characterized (ideally) as a straight line with a 3:1 slope. The "on-channel" response of the receiver would be a line with a 1:1 slope. Any two lines of differing slope will have a point at which they intersect. However, the "intercept" of the third-order and on-channel responses is at a level far higher than the strength of signals receivers can normally handle. Thus, it has to be calculated rather than measured.

The IP3 calculation can be based on a variety of signal levels. One common level is the noise floor (aka "mds") - however, at this level, noise can cause a non-linear response in the real-world circuits of the receiver. Also, it should be noted that IP3 is generally considered to be a measure of a receiver's strong-signal handling ability, thus it is most appropriate to calculate this with signal levels well above the noise floor. In the ARRL Lab, signal levels of S5 are used for the IP3 calculation.

For the Argonaut V, IP3 was also investigated at other signal levels on 20-meters, specifically S3, S7 and S9, as well as the noise floor (MDS). IP3 was also checked at 50 and 100 kHz spacing (S5 and MDS only). Note how IP3 changes as the input signal levels vary (see the Jul/Aug 2002 QEX article "Improved Dynamic-Range Testing" for more information).

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Third-Order Intercept Summary: (All figures in dBm)

Band	Spacing	IP3 - MDS	IP3 - S3 Ref.	**IP3 - S5 Ref.**	IP3 - S7 Ref.	IP3 - S9 Ref.	Notes
3.52 MHz	100 kHz	+6.25	–	+7.55	–	–	1
3.52 MHz	50 kHz	+6.25	–	+7.55	–	–	
3.52 MHz	20 kHz	–5.75	–	–4.45	–	–	2
3.52 MHz	5 kHz	–41.8	–	–30.0	–	–	
14.02 MHz	100 kHz	+8.85	–	+10.1	–	–	
14.02 MHz	50 kHz	+7.35	–	+10.1	–	–	
14.02 MHz	20 kHz	–4.65	–3.4	–3.4	–3.1	–2.35	2, 3
14.02 MHz	5 kHz	–39.2	–31.9	–28.9	–19.6	–5.35	

Notes:
1. Receiver bandwidth set to 500 Hz for all tests.
2. Ten-Tec's specification for IP3 is "20 kHz spacing, ARRL method".
3. A second unit posted similar results (test performed on 20M with S5 levels only).

Second-Order Dynamic Range and Intercept

Test Description: This test measures the amount of 2nd-order mixing that takes place in the receiver and calculates an intercept of the second order response with the on-channel response. Signals at 6 and 8 MHz are presented to the receiver and the resultant output at 14 MHz is measured.

Test Results:

Frequency	Mode	Dynamic Range	IP2 - S5 Ref.	Notes
14.02 MHz	CW	83.7 dB	+46.8	1

1. A second unit was measured at +55 dBm.

Swept Dynamic Range Graphs

The following page shows one of the highlights of ARRL test result reports -- swept graphs of receiver two-tone, third-order IMD dynamic range and blocking dynamic range. These graphs are taken using National Instruments LabWindows/CVI automated test software, with a custom program written by the ARRL Laboratory.

Dynamic range measures the difference between a receiver's noise floor and the receiver's degradation in the presence of strong signals. In some cases, the receiver's noise performance causes receiver degradation before blocking or a spurious response is seen. In either case, if the noise floor is degraded by 1 dB due to the presence of receiver noise during the test, the dynamic range is said to be noise limited by the level of signal that caused the receiver noise response. A noise-limited condition is indicated in the *QST* "Product Review" test-result tables.

Being "noise limited" is not necessarily a bad thing. A receiver noise limited at a high level is better than a receiver whose dynamic range is lower than the noise-limited level. In essence, a receiver that is noise limited has a dynamic range that is better than its local-oscillator noise. Most of the best receivers are noise limited at rather high levels.

The ARRL Laboratory has traditionally used off-channel signals spaced 20 kHz from the desired signal. This does allow easy comparisons between different receivers. There is nothing magical about the 20-kHz spacing, however. In nearly all receivers, the dynamic range varies with signal spacing, due to the specific design of the receiver. Most receivers have filter combinations that do some coarse filtering at RF and in the first IF, with additional filtering taking place in later IF or AF stages. As the signals get "inside" different filters in the receiver, the dynamic range decreases as the attenuation of the filter is no longer applied to the signal. Interestingly, the different filter shapes can sometimes be seen in the graphs of dynamic range of different receivers. In the case of the ARRL graphs, one can often see that the 20-kHz spacing falls on the slope of the curve. Many manufacturers specify dynamic range at 50 or 100 kHz.

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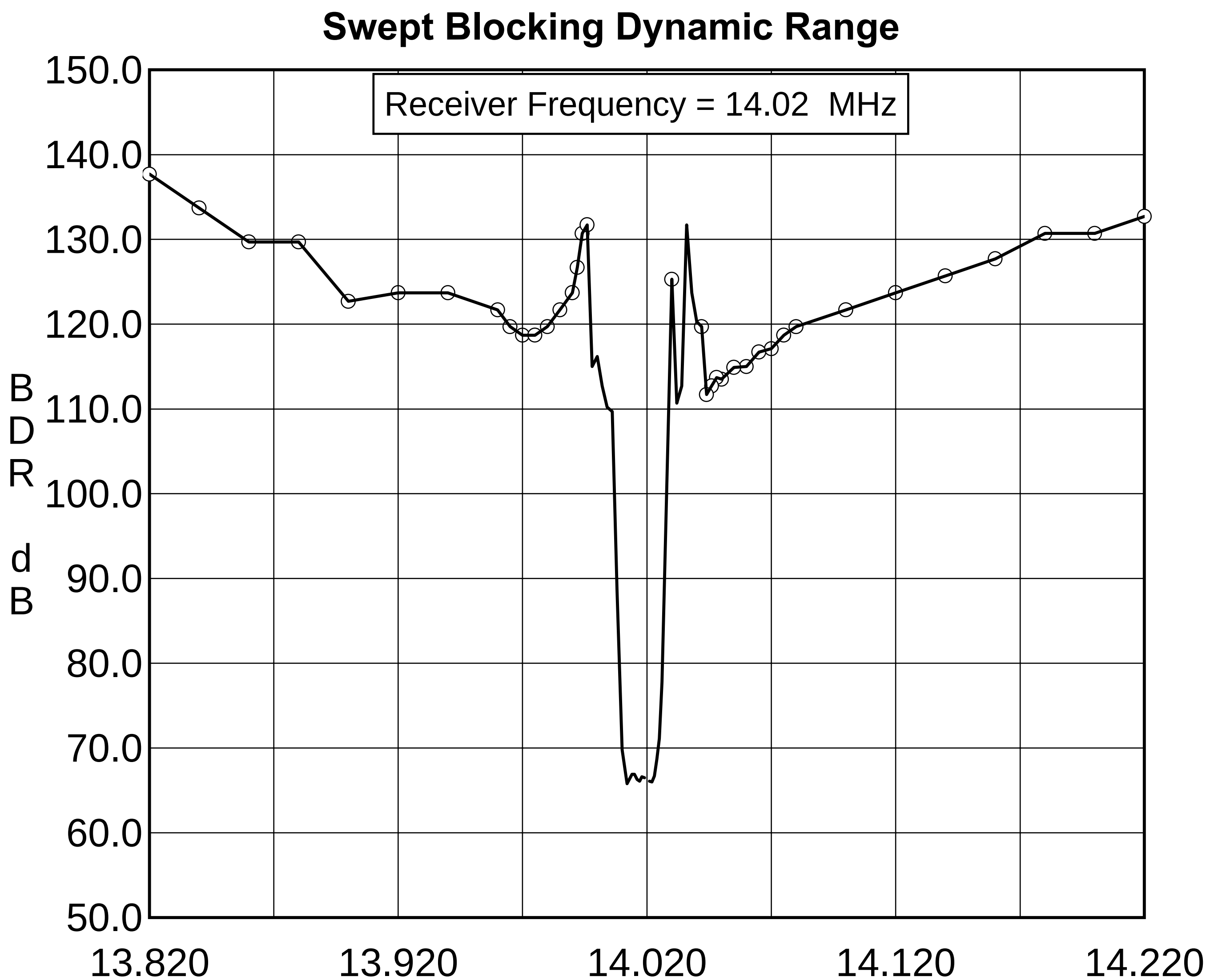
The graphs that follow show swept blocking and two-tone dynamic range. In these tests, the receiver is tuned to a signal on 14.020 MHz, the center of the graph. In the blocking test, the X-axis is the frequency (MHz) of the undesired, off-channel signal. In the two-tone test, the X-axis is the frequency of the closer of the two tones that are creating intermodulation.



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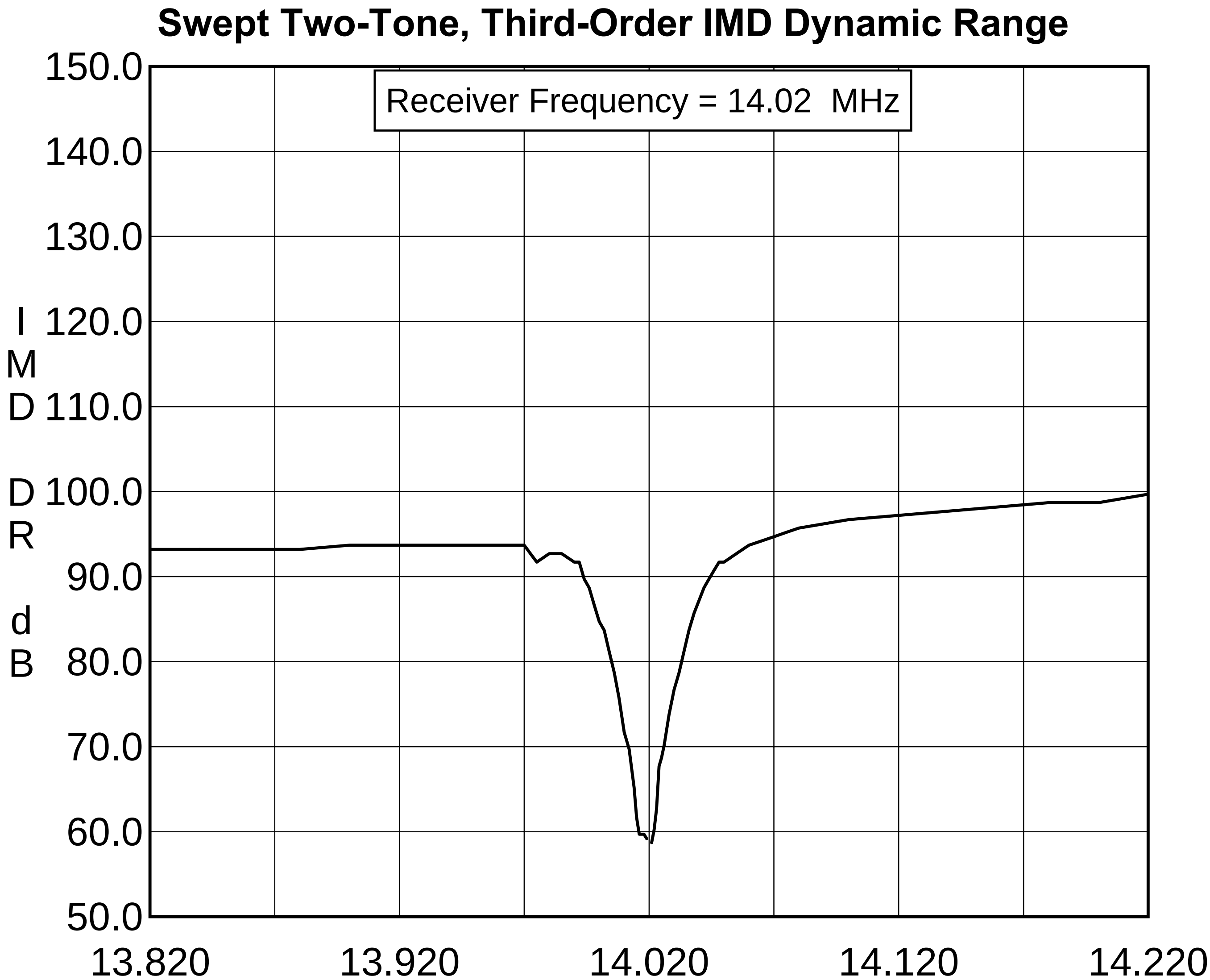

FM Adjacent Channel Selectivity

Test Description: The purpose of this test is to measure the ability of the receiver to reject interference from individual undesired signals while receiving various levels of desired signal. The desired carrier signal will be at 29.000 MHz, modulated at 1000 Hz, and the offending signal will be located at adjacent nearby frequencies with 400-Hz modulation. (NOTE: The SINAD Test in must be performed before this test can be completed.) The greater the number in dB, the better the rejection.

Test Results:

Frequency	Frequency Spacing	Adjacent channel rejection	Notes
29.0 MHz	20 kHz	64.4 dB	

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FM Two-Tone 3rd-Order Dynamic Range

Test Description: The purpose of this test is to determine the range of signals that can be tolerated by the receiver in the FM mode while producing no spurious responses greater than the 12-dB SINAD level. Two signals, f_1 and f_2, of equal amplitude and spaced 20 kHz apart, are injected into the input of the receiver. The signal located 40 kHz from the distortion product being measured is modulated at 1,000 Hz with a deviation of 3 kHz. The receiver is tuned to the Third Order IMD frequencies as determined by $(2f_1-f_2)$ and $(2f_2-f_1)$. The input signals are then raised simultaneously by equal amounts until 25 % distortion, or the 12 dB SINAD point, is obtained. For VHF bands, frequencies 10 MHz outside the amateur band are used to test the wide-band dynamic range. The greater the dynamic range, the better the receiver performance.

Test Results:

Frequency	Frequency Spacing	Dynamic Range	Notes
29 MHz	20 kHz	64.4 dB *	

Notes:

* Test is noise limited. In FM, this results in a reading that is somewhat inaccurate. The actual dynamic range is probably a few dB worse than the figures indicated. While this sounds opposite of what one would expect, because the test is based on a SINAD measurement, the presence of noise means that it takes a stronger signal to have a product equal to the measured noise floor, resulting in a number that appears better than it would be if there were no noise.

IF and Image Rejection

Test Description: This test measures the amount of first IF and image rejection for superhetrodyne receivers by determining the level of signal input to the receiver at the first IF (or image frequencies) that will produce an audio output equal to the MDS level. The test is conducted with the receiver in the CW mode using the 500 Hz, or closest available IF filters. Any audio filtering is disabled and AGC is turned OFF, if possible. The greater the number in dB, the better the image rejection.

Test Results:

Frequency	IF Frequency	First IF Rejection	Image Frequency	Image Rejection	Notes
14.020 MHz	44.997 MHz	72.1 dB	104.015 MHz	84.0 dB	

Audio Output Power

Test Description: This test measures the audio power delivered by the receiver. The manufacturer's specification for load and distortion are used. For units not specified, an 8-ohm load and 10% harmonic distortion are used.

Test Results:

Specified Distortion	Specified Load Impedance	Audio Output Power	Notes
5% T.H.D.	4 ohms	2.72 W	

Audio Hiss

Test Description: This test measures the audio output power at minimum volume with no signal. It gives an indication of the noise (often referred to as "hiss") generated by the audio stages of the receiver.

Test Results:

Specified Load Impedance	Hiss Level	Notes
4 ohms	0.36 mV (ac)	

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IF and Audio Frequency Response

Test Description: The purpose of the IF + Audio Frequency Response Test is to measure the audio frequencies at which the receiver audio drops 6 dB from the peak signal response. The frequency-response bandwidth is then calculated by taking the difference between the lower and upper frequency.

Test Results:

IF Filter Use/Unit Mode	Nominal Bandwidth Hz	Low Freq (Hz)	High Freq (Hz)	Difference (bandwidth)	Notes
CW	500	394	1015	621	1
USB	2.4 kHz	158	2030	1872	
LSB	2.4 kHz	166	2382	2216	
AM	4.8 kHz	111	2642	2531	

Notes:
1. High and low audio frequencies on CW vary with the pitch control.

Squelch Sensitivity

Test Description: The purpose of the Squelch Sensitivity Test is to determine the level of the input signal required to break the receiver's squelch at the threshold. This number is not usually critical. A result anywhere between 0.05 and 0.5 µV is usually useful.

Test Results:

Frequency	Preamplifier	Mode	Threshold	Notes
29.0 MHz	On	FM	0.988 µV	
14.2 MHz	On	SSB	0.11 µV	

S-Meter Sensitivity

Test Description: The purpose of the S-Meter Test is to determine the level of RF input signal required to produce an S9 and S9+20 dB indication on the receiver S meter. This test is performed with the receiver in the CW mode. A traditional S9 signal is a level of 50 µV (an old Collins receiver standard). The Collins standard S unit was 6 dB. This is, however, not a hard and fast rule, especially for LED or bargraph type S meters. On the Argonaut V, S-meter sensitivity was also checked at levels of S3, S5, S7, S9+20 and S9+40 (20M only)

Test Results:

Frequency	S Units	Sensitivity in dBm	ensitivity ı µV	Notes
1.02 MHz	S9	–70.2	69.1	
3.52 MHz	S5	–99.1	2.48	
14.2 MHz	S3	–110.2	0.691	
14.2 MHz	S5	–98.2	2.75	
14.2 MHz	S7	–86.8	10.2	
14.2 MHz	S9	–75.1	39.3	
14.2 MHz	S9+20	–54.0	446	
14.2 MHz	S9+40	–31.5	5.95 mV	

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