Design excellence: R-1051, the swan song of vacuum tube sets

The architecture defined by Collins in the 51J series, in R-390 family and their derivative receivers suffered some limits. The most severe one derived from the use of independent oscillators, the PTO and the two separate oscillators, each tuned to different frequencies by means of selectable quartz crystals. Even if the set of crystals for each receiver was thoroughly selected and aged, each crystal suffered an initial small deviation from its nominal value and, what was worse, it was subjected to an unpredictable drift through the life of the receiver. Due to the said tolerances and drifts, operating procedures asked both for the dial calibration against an internal reference after each band switching and frequent overall performance checks. The next step in top performance receivers was the introduction of the frequency synthesizer, locking all the beating oscillators to a single frequency reference. The early synthesized receivers in 1960 were the bulky FRR-59 and the shipboard version WRR-2, each using over than 60 tubes. But in those days semiconductors were mature enough to replace vacuum tubes and the revolution went on rapidly.

The R-1051(x)/URR was the latest communication receiver still using vacuum tubes, even if just two tubes in the RF module. Designed by General Dynamics for US Navy, its production started in 1964 and continued with several variants and several suppliers well in the ‘90s. Probably it is still in service today. No other communication receiver can claim a nearly comparable service life.

General description

R-1051(*)/URR is a digitally tuned receiver covering from 2.0 to 29,999MHz and capable of receiving LSB, USB, ISB, AM or CW transmissions. Other types of transmission, FSK, MCW, compatible AM and FAX can be also received, provided the use of suitable ancillary equipment.

The receiver uses a triple conversion superheterodyne architecture. Tuning is digital with 5 frequency controls, megacycles and kilocycles. A further control selects the increments, 0.5 or 0.1KHz, depending upon the variants, and operates as a continuous vernier between calibrated steps. Accuracy in calibrated position is better than +/-0.05Hz at 5MHz; frequency stability is better than 0.01ppm (parts per million) per day over 0 to +50 degrees C. Sensitivity is better than 1 microvolt for 10dB signal to noise ratio in SSB, 2 microvolts in CW/FSK and 4 microvolts in AM mode.

IF frequencies: first 20 or 30MHz, depending upon the selected band; second IF 2.85MHz, third IF 500KHz. IF rejection better than –75dB, Image rejection better than –80dB.

Power requirements: 115VAC, 48 to 450Hz, single phase, 55W.

Known variants

- **R-1051/URR** - 0.5 kc steps, metal chains, dual meter, discrete semiconductors + 2 tubes, "six-pack" frame, early deliveries in 1964 by General Dynamics at $25,250 each. Also license built in Italy by Elmer (Montedel).
- **R-1051A/URR** - 0.5 kc steps, metal chains, dual meter, discrete semiconductors + 2 tubes, "six-pack" chassis frame. Elmer (Montedel) (?) only known manufacturer.

- **R-1051B/URR** - 0.1 kc steps, metal chains, dual meter, discrete transistors + 2 tubes, "six-pack" chassis frame. Manufactured by Bendix (Allied Signal)
- **R-1051C/URR** - 0.1 kc steps, metal chains, dual meter, black face, discrete transistors + 2 tubes, "six-pack" frame. Probably from General Dynamics and Radionics.
- **R-1051D/URR** - 0.1 kc steps, probably metal chains, single meter, SSI and MSI logic + discretes + 2 tubes, "six-pack" chassis. Low-cost version sold by General Dynamics at $16,830 apiece.
- **R-1051E/URR** - 0.1 kc steps, plastic chains, single meter, SSI and MSI logic + discretes + 2 tubes, "six-pack" chassis frame. Made by Bendix (Allied Signal) and sold for $25,250 apiece.
- **R-1051F/URR** - 0.1 kc steps, plastic chains, single meter, SSI and MSI logic + discretes + 2 tubes, card cage. Manufactured by Stewart-Warner and sold for $21,210 apiece.
- **R-1051G/URR** - 0.1 kc steps, plastic chains, single meter, SSI and MSI logic + discretes + 2 tubes, card cage. Stewart-Warner.
- **R-1051H/URR** - 0.1 kc steps, plastic chains, single meter, SSI and MSI logic + discretes + 2 tubes, card cage. Made by Stewart-Warner and sold for $50,490 apiece.

The design

The simplified block diagram of the R-1051B/URR receiver is very similar to the one of the Elmer R-1051A/URR on display in the museum:

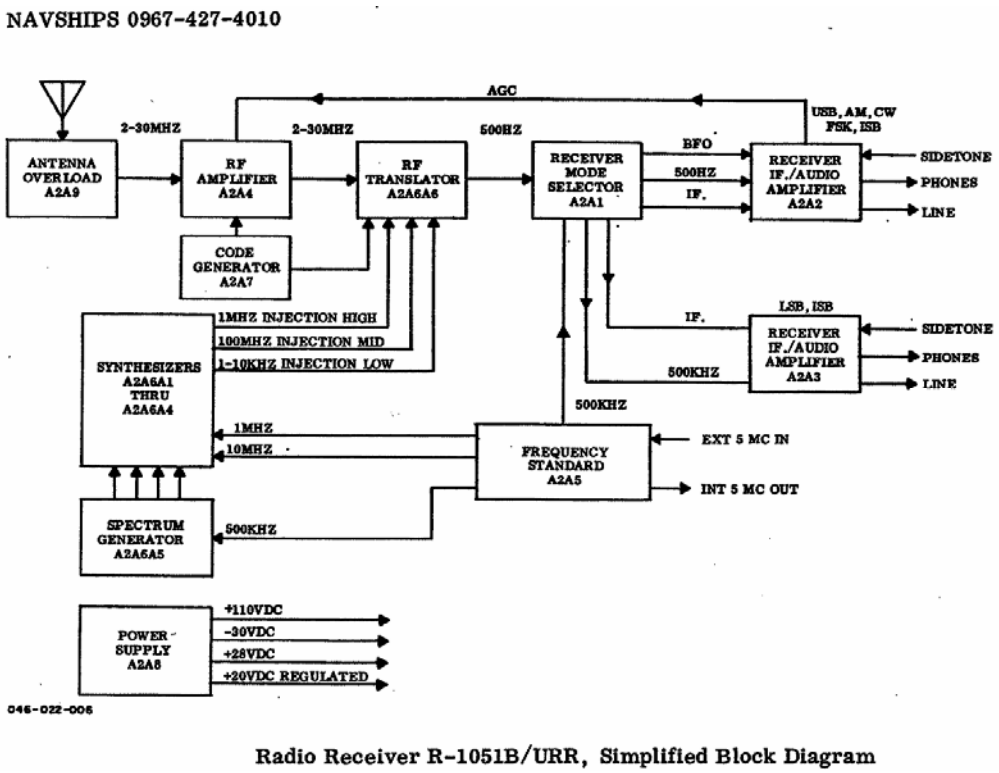


Fig. 1 - Block schematic diagram. Click to enlarge.

In the models up to the ‘E’ suffix six plug-in assemblies contain most of the circuits, with the exception of the power supply, the Mcs code generator and the antenna relay board. The frame distributes supply voltages and signals to the six modules. The setting of Kcs knobs from the front panel is distributed through metal chains to the RF fine tuning turrets and to the involved subassemblies of the frequency synthesizer / translator.

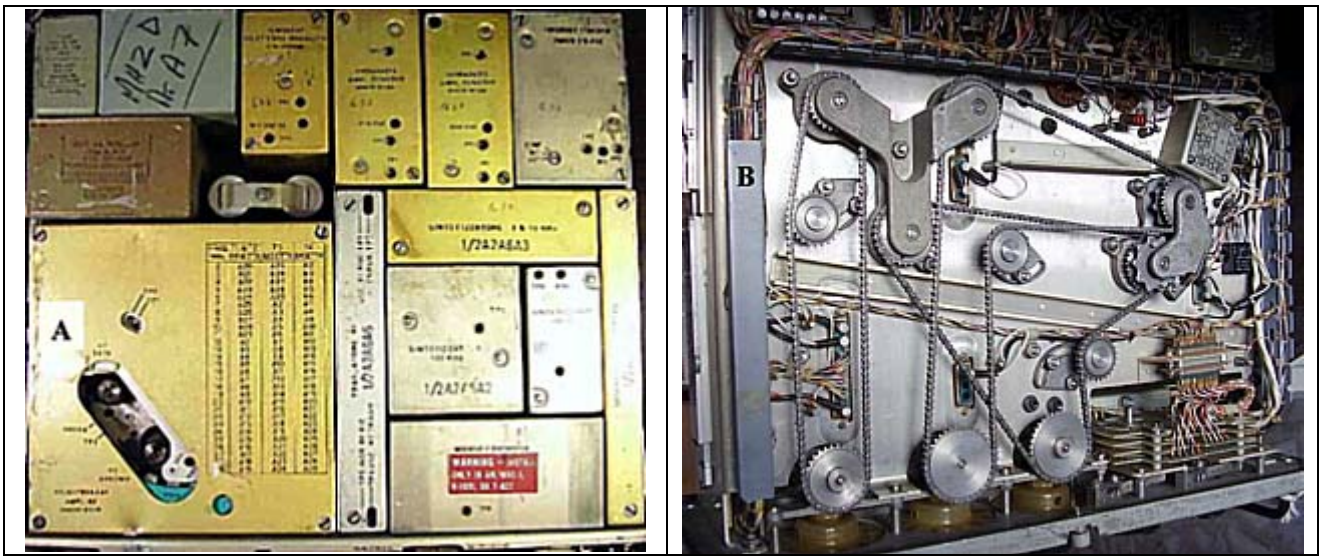


Fig. 2 – A, the frame complete with the six plug-in assemblies. The large subassembly at bottom right is the synthesizer / translator and includes six sub-units. B, bottom view showing the tuning chains. Click each image to enlarge.

Plug-in modules are:

- Frequency Standard Assy, A2A5
- RF Amplifier Assy, A2A4
- Frequency Translator/Synthesizer Assy, A2A6
- Receiver Mode Selector Assy, A2A1
- IF – Audio Amplifier, 2 each USB and LSB channels, A2A2 and A2A3

Let us show some details of these subassemblies (click on images to enlarge).

Fig. 3 - The frequency standard unit operates from a stable 5 MHz crystal oscillator housed in a temperature controlled oven. The frequency reference can be switched to an external 5 MHz standard or even can be compared with the external standard and the blinking of a built-in lamp indicates the zero-beat adjustment. By multiplication and division of the reference signal, the module also generates signals at 500KHz, 1MHz and 10MHz, used in the receiver. Click to enlarge.

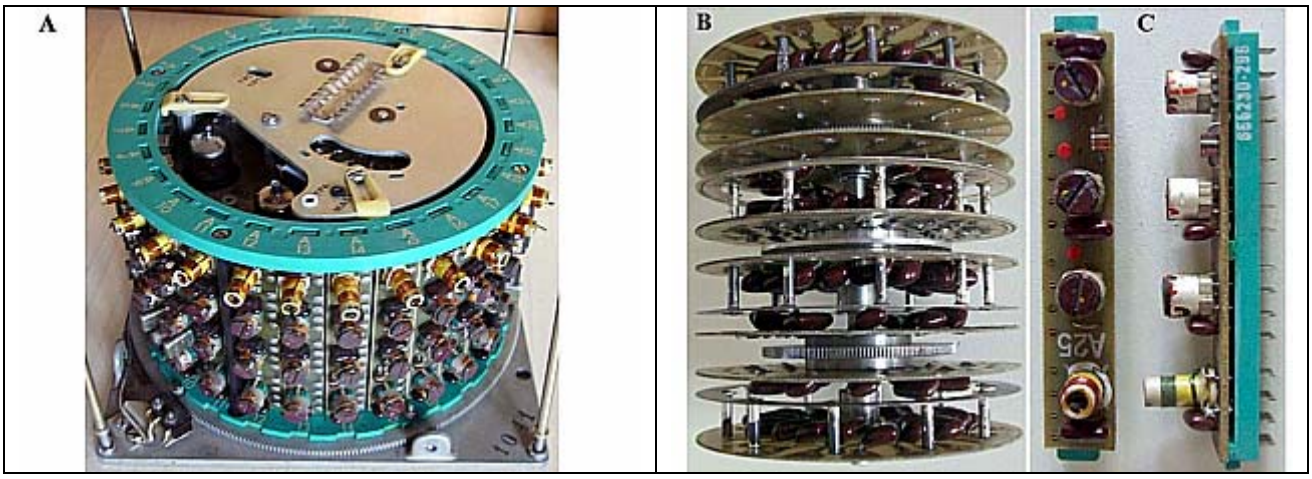


Fig. 4 - A and B) The RF assembly, the only one that includes the two vacuum tubes, is very complex. A motorized rotary turret, driven according to the position of the two Mcs knobs through a code generator, selects one out the 28 tuning strips, one for each MHz band. Multiple independent-plate rotating subassemblies which contains the fine tuning capacitors is mounted inside the Mcs turret and driven by the 100 and 10 Kcs tuning knobs. Four tuned circuits, two of them in input, provide the required selectivity. The gain of both the vacuum tubes is controlled by the AGC circuit. Click on images to enlarge.

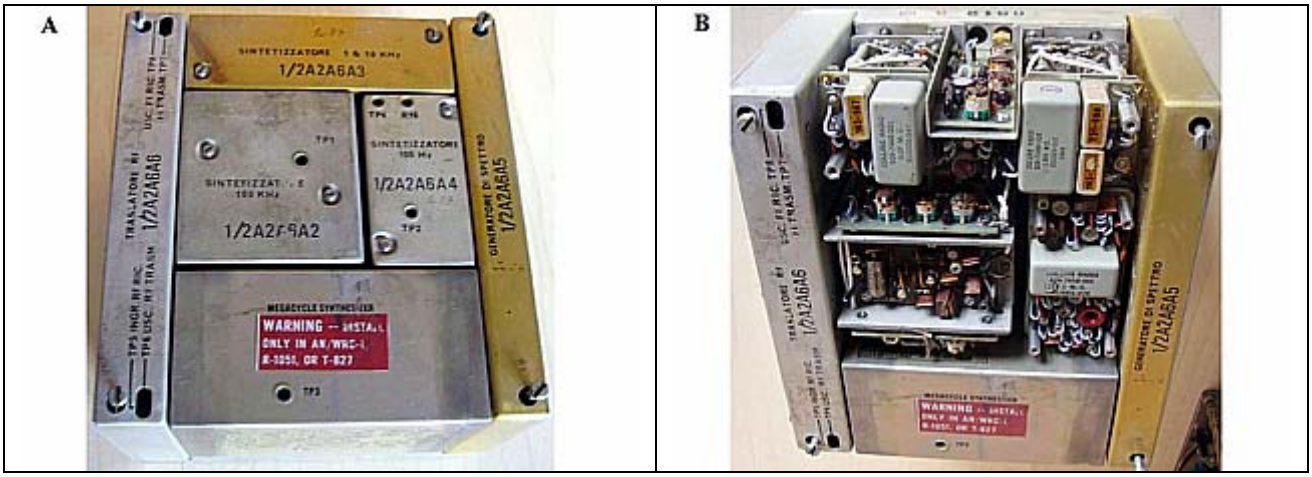
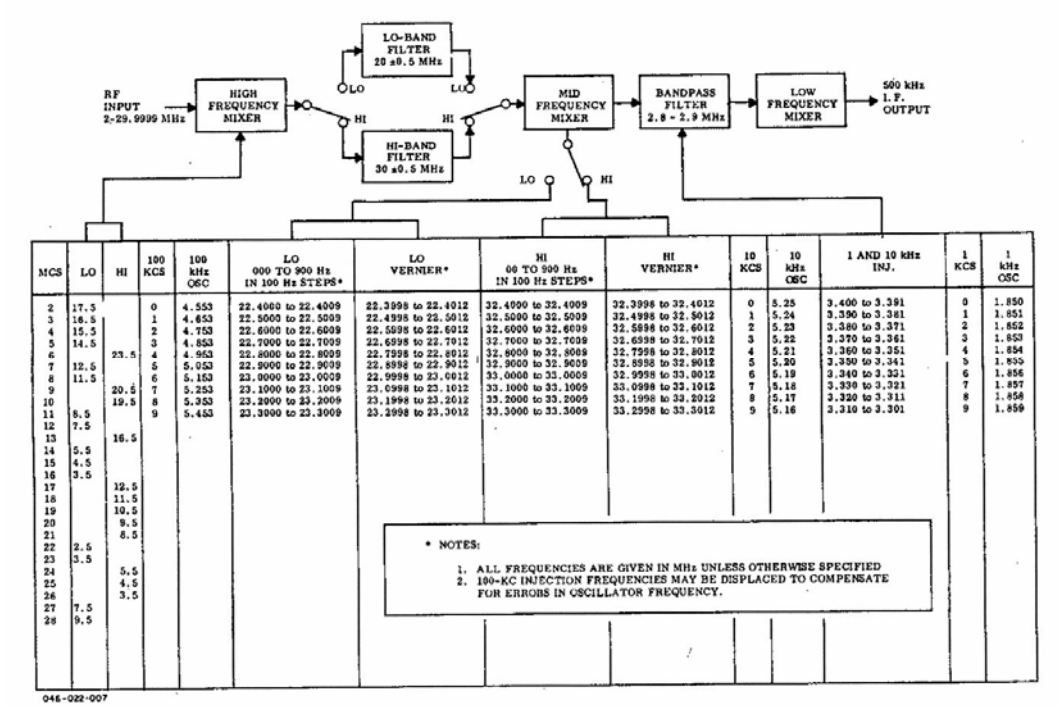


Fig. 5 - The translator/synthesizer assembly actually includes six subassemblies on a common distribution subchassis, to generate the beating frequencies and the three mixers. A spectrum generator module feeds the three synthesizers related to Mcs, 100Kcs and selections 10/1Kcs. The conversion scheme and the related frequencies in the 28 bands are given in the following figure. Click on images to enlarge.



MCS	LO	HI	100 KCS	100 kHz OSC	LO 900 TO 900 Hz IN 100 Hz STEPS*	LO VERNIER*	HI 00 TO 900 Hz IN 100 Hz STEPS*	HI VERNIER*	10 KCS	10 kHz OSC	1 AND 10 kHz INJ.	1 KCS	1 kHz OSC
2	17.5		0	4.553	22.4000 to 22.4009	22.3998 to 22.4012	32.4000 to 32.4009	32.3998 to 32.4012	0	5.25	3.400 to 3.391	0	1.850
3	16.5		1	4.653	22.5000 to 22.5009	22.4998 to 22.5012	32.5000 to 32.5009	32.4998 to 32.5012	1	5.24	3.390 to 3.381	1	1.851
4	15.5		2	4.753	22.6000 to 22.6009	22.5998 to 22.6012	32.6000 to 32.6009	32.5998 to 32.6012	2	5.23	3.380 to 3.371	2	1.852
5	14.5		3	4.853	22.7000 to 22.7009	22.6998 to 22.7012	32.7000 to 32.7009	32.6998 to 32.7012	3	5.22	3.370 to 3.361	3	1.853
6		23.5	4	4.953	22.8000 to 22.8009	22.7998 to 22.8012	32.8000 to 32.8009	32.7998 to 32.8012	4	5.21	3.360 to 3.351	4	1.854
7	12.5		5	5.053	22.9000 to 22.9009	22.8998 to 22.9012	32.9000 to 32.9009	32.8998 to 32.9012	5	5.20	3.350 to 3.341	5	1.855
8	11.5		6	5.153	23.0000 to 23.0009	22.9998 to 23.0012	33.0000 to 33.0009	32.9998 to 33.0012	6	5.19	3.340 to 3.331	6	1.856
9		20.5	7	5.253	23.1000 to 23.1009	23.0998 to 23.1012	33.1000 to 33.1009	33.0998 to 33.1012	7	5.18	3.330 to 3.321	7	1.857
10		19.5	8	5.353	23.2000 to 23.2009	23.1998 to 23.2012	33.2000 to 33.2009	33.1998 to 33.2012	8	5.17	3.320 to 3.311	8	1.858
11	8.5		9	5.453	23.3000 to 23.3009	23.2998 to 23.3012	33.3000 to 33.3009	33.2998 to 33.3012	9	5.16	3.310 to 3.301	9	1.859
12	7.5												
13		16.5											
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25		4.5											
26		3.5											
27	7.5												
28	9.5												

* NOTES:
1. ALL FREQUENCIES ARE GIVEN IN MHz UNLESS OTHERWISE SPECIFIED
2. 100-KC INJECTION FREQUENCIES MAY BE DISPLACED TO COMPENSATE FOR ERRORS IN OSCILLATOR FREQUENCY.

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Fig. 6 - PLL circuits are used across the entire synthesizer, even in the variable frequency oscillator of the fraction of Kcs uncalibrated position. The sole exception is the 100KHz synthesizer, where the oscillator is locked on the reference signal by a very smart error canceling loop, involving two of the mixers. Click to enlarge.

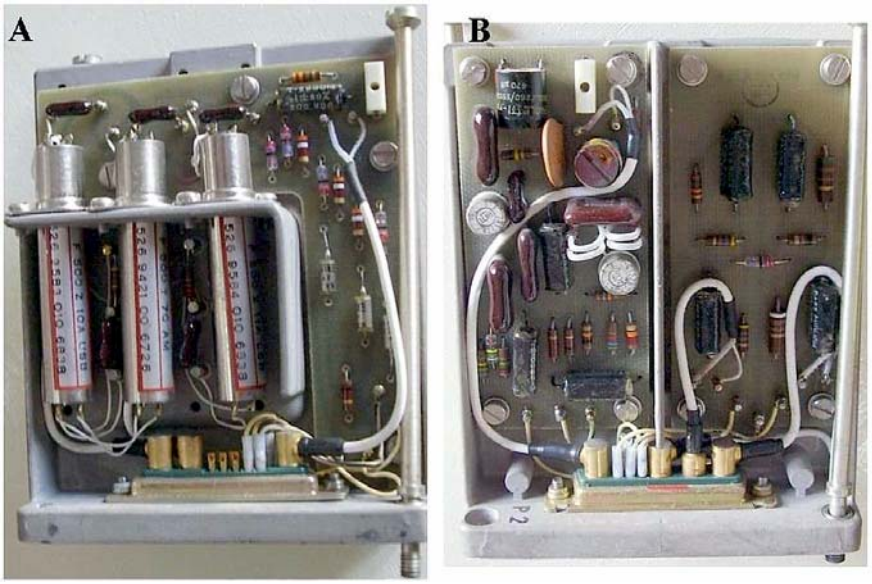

Fig. 7 - The mode selector, at the output of the third mixer, routes the IF signal to the appropriate filter(s), depending upon the selected mode, AM, LSB or USB. This unit also includes the BFO generator, phase-locked to the reference and variable from 496.5 to 503.5KHz, and a diode gate to feed the product detectors in the IF/audio assemblies with the required 500KHz carrier. Click to enlarge.

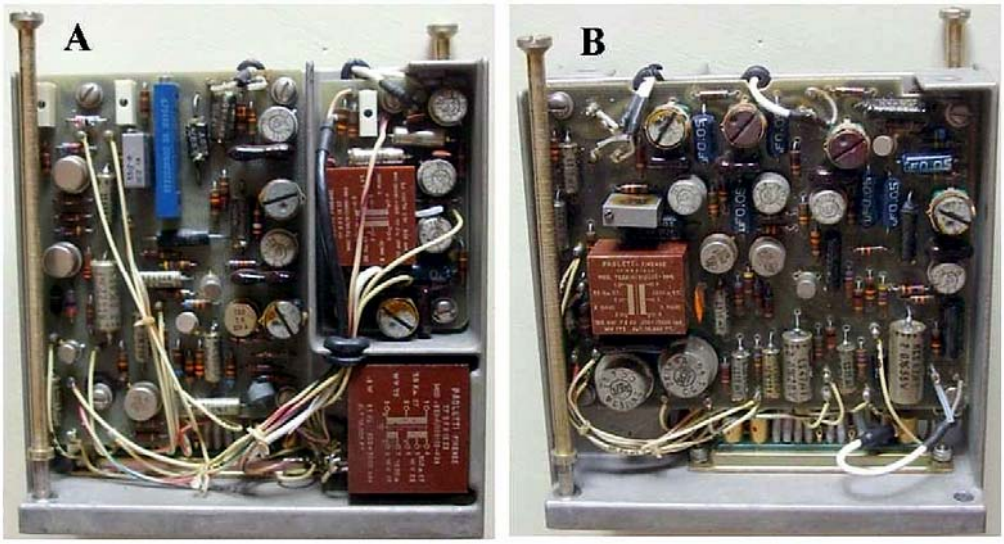

Fig. 8 – The IF/Audio amplifier module. Two identical modules are used, one for each channel in ISB mode. Each module contains a gain-controlled 500KHz IF amplifier, a product detector driven by the 500KHz gate of the mode selector module, an AM detector, a step AGC circuit and an audio amplifier. Click to enlarge.

Some notes

The R-1051 was designed to outperform any other receiver in use before. The operator had to select the right frequency and the wanted mode and the receiver performed the rest of the job, even selecting the proper bandwidth or the best AGC response, no uncertainty, no drift.

Unfortunately even this receiver has some drawbacks, other than the top price paid by US Navy and I believe by Italian Marina Militare. The service of plug-in modules is very very difficult without the proper extenders. What is worst is that it is almost impossible to sweep even a limited band, since its digital tuning requires the setting of five or six knobs, some very difficult to operate, for each new frequency.

Last edited by Emilio Ciardiello in November 2016