ELECTRONICALLY TUNED INTEGRATED X-BAND SUPERHETERODYNE RECEIVER*

by

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This paper describes the development of a unique, integrated, low-noise, X-band, sweeping superheterodyne receiver. The general configuration of the receiver (Figure 1) was dictated by the requirements for typical microwave sweeping receivers, which include low noise figure, large dynamic range, high conversion gain, good image rejection, narrow instantaneous IF bandwidth, wide tuning range, and rapid sweep capability. Figure 1 includes a wideband tunnel-diode amplifier (TDA) to provide an acceptably low noise figure, considering the relatively undistinguished noise performance typical of wideband microstrip mixers when driven by solid-state local oscillators and degraded by high-frequency IF amplifiers. The mixer is of the image-rejection type, consisting essentially of two identical balanced mixers with proper phasing at the signal, local oscillator (LO), and IF-output ports to provide image cancellation. A Gunn device was selected for the internal oscillator, as this type provides ample fundamental X-band power, and is sufficiently quiet to permit electronic tuning with a moderate resonator Q. The latter enables the oscillator to be varactor tuned, thereby avoiding the heavy, bulky, power-consuming electromagnets that are associated with YIG-tuned X-band devices.

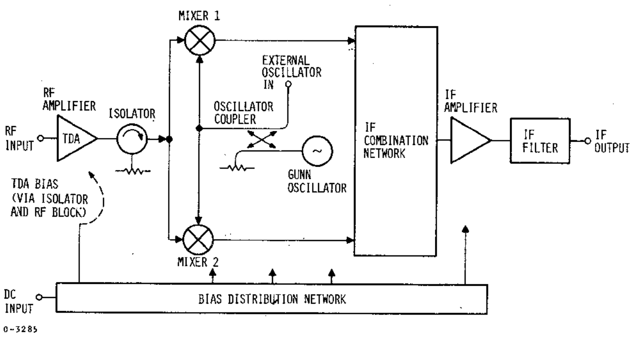

Figure 1. Receiver Block Diagram

All the components of Figure 1 were integrated within a single housing (Figures 2 and 3). This housing contained separate compartments arranged in two layers for compactness. These metallic compartments, joined by short lengths of subminiature coax, accommodated previously tested components and prevented the box resonances and higher-mode coupling which could occur in a single large-volume housing. An RF signal entering the receiver at J1 reaches the TDA, a key component of which is a three-port circulator employing an embedded YIG disc. This circulator provides an isolation of 23 ±3 dB and a forward loss of 0.5 ±0.25 dB per pass across the 8 to 10 GHz band. The TDA substrate has been drilled through to accommodate a packaged tunnel diode whose lower flange is soldered to the ground plane metalization. The upper contact of the diode is connected by beam leads to a stabilizing network, a pair of tuning stubs, and a quarter-wave transformer which determines the midband gain. With the bias set at 165 mV, the gain of this TDA is 11.5 ±1.5 dB and the noise figure is 6.0 ±0.4 dB across an 18% band from 8.1 to 9.7 GHz. This bandwidth represents a two-fold improvement over the closest prior art.[1,2,3] After the RF signal leaves the TDA, it enters the isolator shown in the upper left-hand corner of Figure 2. The RF signal then enters the upper deck of the mixer, which has been described in detail by Kurpis and Taub.[4] The internal oscillator contains a packaged Gunn-effect device and two chip varactors fabricated by the AIL Central Research Group. These varactors are connected in series at RF, and in parallel at dc. The circuit also contains a half-wave open-circuited stub which completes the equivalent resonator associated with the Gunn-device tuning, and a tapered microstrip line which maximizes the power output. This oscillator provides a power output of 14 to 36 mW across the entire electronic tuning range of 8.3 to 9.3 GHz.

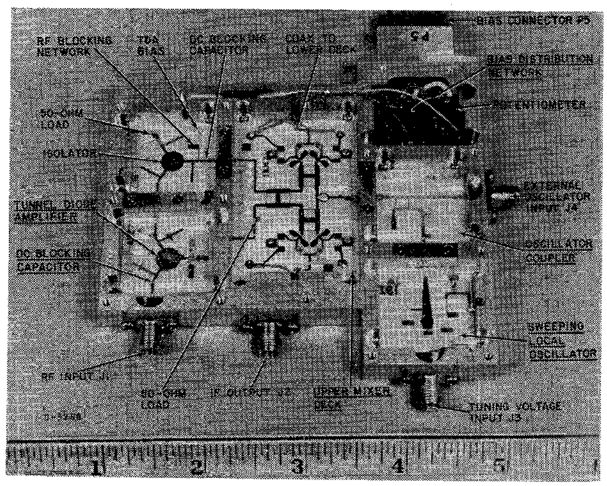

Figure 2. Top View of Receiver

The two IF outputs of the mixer are routed to the lower deck by means of subminiature coaxial lines, at which point they enter the IF combining network[4] (Figure 3). Upon combination, the IF signal is fed to the IF amplifier, which contains four channel-packaged silicon NPN transistors. This amplifier exhibits a gain of 38 ±0.5 dB and a noise figure of 2.0 to 2.5 dB across the 135 to 235 MHz band. The amplifier IF output reaches J2 after passing through the IF band-pass filter. This lumped-element filter provides a half-power bandwidth of 7 MHz and includes a complementary branch which match terminates the amplifier throughout its active band.

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Figure 4 summarizes the major performance characteristics of the receiver together with some of the TDA characteristics as a reference. With external LO drive, the measured overall gain was 37 ±3 dB and the image rejection was a minimum of 20 dB across the 8 to 10 GHz band. The same overall gain and image rejection were obtained across the 8.5 to 9.4 GHz band with the internal Gunn oscillator. With the mixer driven by an external klystron, the receiver noise figure was 7.8 ±0.5 dB from 8.15 to 9.60 GHz. Over the portion of this band tuned by the Gunn oscillator, the overall noise figure increased to 8.3 ±0.7 dB under internal LO operation. The TDA noise figure is also plotted to show the potential improvement in receiver noise figure, achievable with higher-Q tuning varactors and an additional stage of preamplification.

The receiver described in this paper is the first of its kind to integrate, within a minimum volume, all the components necessary for a wideband, low-noise, rapid scan, imageless, X-band receiver. This receiver is superior to the closest prior art[2,5,6] in terms of electronic tuning range, total frequency coverage, conversion gain, and image rejection. The receiver package occupies a volume of only 5.9 in^3, less connectors, and weighs 6.4 oz.

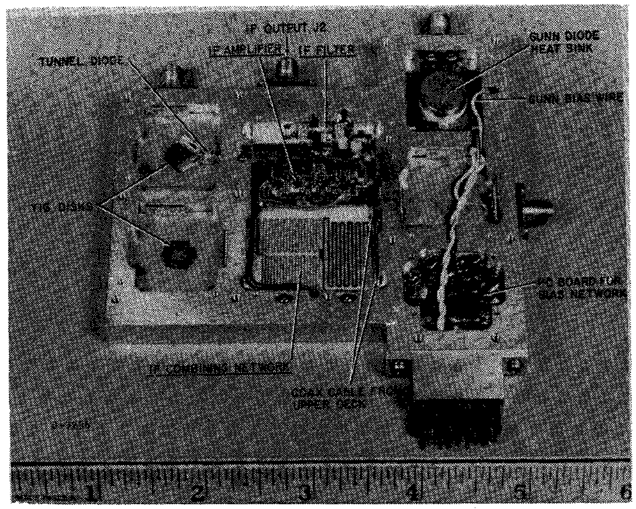

Figure 3. Bottom View of Receiver

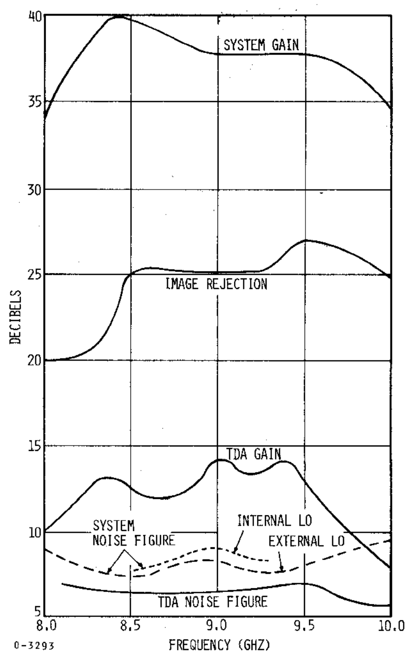

Figure 4. Measured Performance of Receiver

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