Cryogenic Microwave Channelized Receiver

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(Invited Paper)

***Abstract*— The channelized receiver being presented demonstrates the use of high temperature superconductor technology in a microwave system setting where superconductor, microwave-monolithic-integrated-circuit, and hybrid-integrated-circuit components are united in one package and cooled to liquid-nitrogen temperatures. The receiver consists of a superconducting X-band four-channel demultiplexer with 100-MHz-wide channels, four commercial monolithically integrated mixers, and four custom-designed hybrid-circuit detectors containing heterostructure ramp diodes. The composite receiver unit has been integrated into the payload of the second-phase NRL high temperature superconductor space experiment (HTSSE-II). Prior to payload assembly, the response characteristics of the receiver were measured as functions of frequency, temperature, and drive levels. The article describes the circuitry, discusses the key issues related to design and implementation, and summarizes the experimental results.**

I. Introduction

DISSIPATION losses in passive circuit elements are among the dominant causes of concern in the design of high-performance microwave system components. Aside from decreased signal amplitudes, adverse effects include increased noise figures, reductions in dynamic range, and impaired frequency selectivity. The classic solution is to either minimize dissipation losses by resorting to physically large structures with low current densities, or to provide loss compensation with the help of active circuit schemes. The development of high temperature superconducting materials has added an attractive alternative. When employed in thin-film planar form, such materials permit the realization of low-loss passive circuits that are noted for their compactness and topological simplicity.

An inherent drawback of any superconductor-based circuit approach is the need for cryogenic cooling. Although adequate cooling, in many instances, can be provided by closed-cycle refrigeration units that are remarkably small, prime power requirements and overall bulk still present a constant challenge to the viability and economics of microwave superconductor applications. Additionally, there are potential concerns about power- and frequency-dependent circuit behavior. Despite these complications there remains a select group of microwave applications for which reliance on high temperature superconductors can offer a competitive advantage.

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Prominent among superconductor uses at microwave frequencies are high-Q filters. They typically derive from conventional normal-metal structures and can hence profit from a wide range of established design options and procedures. Performance advantages as well as the conceptual and topological simplicity of the approach are among the principal factors that help offset the required investment in refrigeration. A way to further amortize the investment is to include, in the cryogenic package, other system components that will benefit from operating at low temperatures. Many components that contain semiconductor devices fall into this category. The present channelized receiver demonstrates such an arrangement.

Detailed descriptions of the receiver and its main components are contained in Section II. Included are discussions of issues that relate to the special requirements imposed on design and fabrication by the need for the receiver to operate at liquid-nitrogen temperatures in a space-based environment. Section III presents measured performance characteristics, recorded as functions of frequency, incident signal level, and temperature. Conclusions contained in Section IV summarize the experiences gained from the work and offer comments on the perceived role of superconducting circuitry in emerging high-frequency systems applications.

II. Receiver Design and Implementation

Commensurate with the objective of demonstrating the integrated use of dissimilar technologies at cryogenic temperatures, the channelized receiver simultaneously engages three different methods of circuit implementation. The receiver's microwave front-end comprises a superconducting frequency demultiplexer in planar form, whose task is to separate incident signals into four narrowband channels. After channelization, the signals are downconverted to a lower intermediate-frequency band. The employed downconverters are off-the-shelf microwave-monolithic-integrated-circuit (MMIC) mixer chips, with pertinent local oscillation signals supplied from sources external to the cold package. A last set of subcomponents comprises an array of hybrid-integrated-circuit detectors. They were included to minimize the thermal load on the spacecraft's cooling system by providing low-frequency output responses that could be extracted from the cold package through small-diameter, high-thermal-impedance cables. Due to the limited cooling capacity of the spacecraft, the receiver did not incorporate signal amplification means that are commonly part of a receiver. The original intent had been to capitalize on the improved performance capabilities of transistors at reduced temperatures by including a low-noise

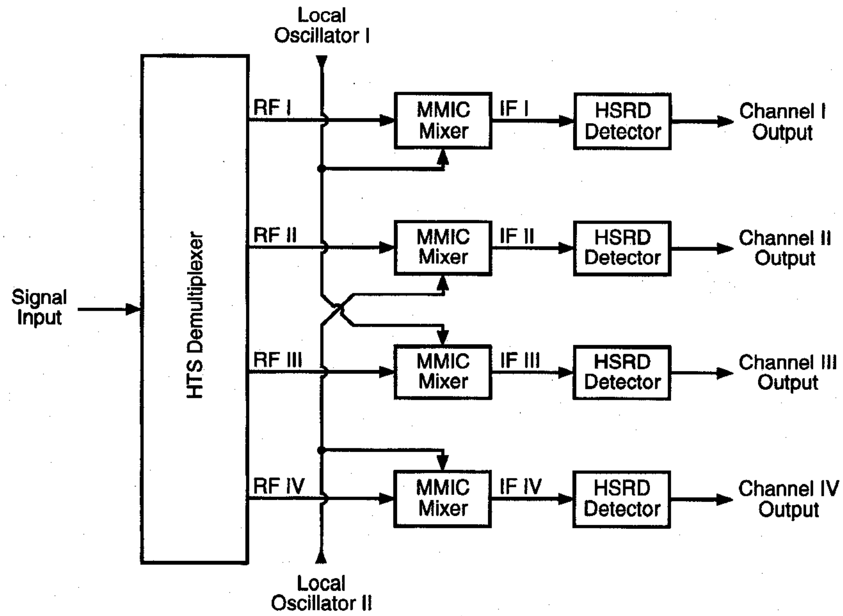

Fig. 1. Block diagram of the channelized receiver, comprising a high temperature-superconductor (HTS) demultiplexer, four MMIC mixers, and four heterostructure ramp diode (HSRD) detectors.

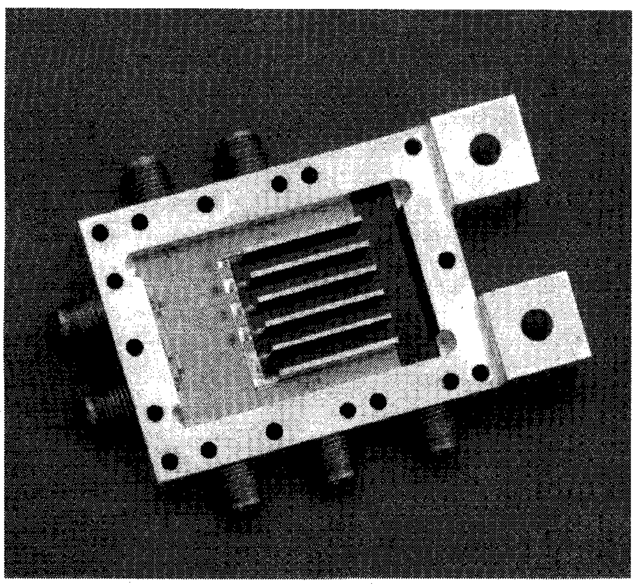

Fig. 2. Photograph of the cryogenic channelized receiver assembly.

amplifier in each of the four signal channels. A block diagram of the implemented receiver is given in Fig. 1. The composite unit itself, with the cover removed, is shown in Fig. 2.

A primary concern in the design of a microwave receiver is the threat of front-end saturation caused by large interference signals, hampering signal identification, and compromising receiver sensitivity. To help guard against such effects, a preselection filter is often employed to suppress out-of-band disturbances incident on the receiver. The filter, due to its strategic up-front position, must not only provide good selectivity, but must also exhibit low insertion loss to prevent undue degradation of receiver noise characteristics. The task can be especially challenging if in-band preselection is sought, for which a contiguous bank of high-Q filters is required. As alluded to earlier, it is specifically in this type of application where superconductor-based solutions show particular promise. They can not only provide high selectivity through exclusive reliance on purely passive, very-low-loss circuit elements, but also offer noise advantages by operating at low temperatures. The superconducting front-end demultiplexer was seen as an opportune means to showcase the technology in accordance with the overall objective of the parent project.

At the time the experiment was conceived, substrates coated with superconducting material on both sides, as required for the envisioned microstrip implementation of the demultiplexer, were not abundantly available. In order to conserve substrate area, a space-efficient manifold solution was adopted. The design procedures for arriving at the solution have been described in detail elsewhere [1]. The employed technique makes generalized use of logarithmic-periodic principles to achieve compactness without the design difficulties normally associated with a manifold-type approach. The modified-logarithmic-periodic configuration chosen for the receiver comprises a trunk line with low-pass properties that distributes an incoming signal among four contiguous-band channel filters with constant 100-MHz-wide passbands. Each of these filters consists of two capacitively end-coupled half-wave resonators that connect to the trunk line through half-wavelength 50-Ω transmission lines. Consistent with underlying logarithmic-periodic principles, the demultiplexer includes one additional channel filter that is terminated internally in a 50-Ω load and serves as part of the input matching network. To suppress crosstalk between adjacent channels, the filters occupy separate substrates, isolated from each other by metal walls. The 50-Ω half-wavelength connector lines establish nonresonant zones where the substrates could be spliced together with minimal sensitivity of performance characteristics to fabrication tolerances. The result is a filter bank composite made up of six substrate segments altogether. They are recognizable in the photograph by their dark appearance, although the microstrip circuit patterns contained on the substrate segments are not easy to discern against the same-colored background.

A frustrating aspect of cryogenically operated circuitry is the need to contain it in a vacuum, thereby denying convenient access for purposes of post-fabrication adjustments. To minimize the potential need for such adjustments, in the present context, an electromagnetic field solver was used to accurately dimension critical circuit elements, such as the series-connected gap capacitors in the channel filters. As a further cautionary measure, the demultiplexer was laid out so that all of its six segments could be fabricated from a single 1-inch-square substrate. The size corresponded to the largest area over which high temperature superconducting thin films could be deposited with acceptable uniformity at the time the design was initiated. Spatial restrictions limited implementation options, consequently, to end-coupled channel filters of second order. In return, random offsets of channel center frequencies due to substrate tolerances and variances in film properties could be kept to a minimum, a particular concern in contiguous-band situations like the one being described.

The demultiplexer circuit pattern was etched from a film of Yttrium-Barium-Copper-Oxide (YBCO), approximately 5000 Å thick, that had been deposited on the top side of a polished 0.010-inch-thick MgO substrate. The back side of the substrate was coated with a 1-μm-thick YBCO film that served as superconducting ground plane for the microstrip structure. (It is the dark-colored YBCO ground plane that projects through the transparent substrate and gives the areas occupied by the demultiplexer their dark appearance in the photograph.) Both films were deposited by pulsed laser deposition in accordance with established procedures [2]. After dividing the substrate into six separate pieces to accommodate metal isolation walls between adjacent channels, two layers of silver and an intermediary nickel diffusion barrier layer were e-beam evaporated onto the YBCO ground plane of each piece, followed by annealing in an oxygen furnace. The annealed silver provided a low-resistance contact to the YBCO material without compromising its superconductive properties. The intermediary nickel layer was incorporated as a precautionary measure to prevent possible contamination of the YBCO material during subsequent fabrication steps. It had been observed, earlier, that common solders, when in direct contact with thin YBCO films, had the tendency to penetrate into the films, alloy with them, and degrade their quality. Due to the presence of the nickel barrier, the final layer of silver, which was chosen for its excellent compatibility with the indium-based low-temperature solder, needed to be made only as thick as required to insure reliable solder attachment of the substrate pieces to the package. To help stem depletion of the silver during the soldering process, the pieces were mounted employing a solder with a three-percent silver content. In contrast to the soldered ground-plane attachments, the top-plane YBCO microstrip patterns associated with individual substrate pieces were interconnected using 0.001-inch-diameter gold wires. Conventional wire bonding to YBCO had not proven effective. Consequently, all wire attachments to YBCO structures were established with dabs of conductive epoxy. The quality and reliability of these attachments were found to be as good, for high-frequency signals, as regular gold-to-gold bonds.

One of the most significant challenges confronted during the design of the receiver was the need to bind the fragile single-crystal MgO substrate pieces to the package in a manner that could withstand the mechanical stresses of cycling over wide temperature spans and also survive stringent shock and vibration testing for space qualification. Early consideration was given to the use of clamps to hold floating substrate pieces in place, thereby sidestepping the issue of disparate thermal expansion coefficients among adjoining materials. Although clamp arrangements were successfully employed in the past, the reliance on solder-based substrate attachment techniques appeared as the more prudent option to pursue. This meant that the package had to be fabricated from material with thermal expansion properties similar to those of MgO. A good match was found in Thermkon 76, a tungsten-copper alloy used commonly for semiconductor device carriers. The entire receiver package was consequently made from this material. To enable soldering, the package had to be silver plated. A thin nickel barrier underneath the silver was added to prevent outdiffusion of copper from the alloy into the silver, from where it could have diffused into the indium solder and caused brittleness. The principal drawback of the tungsten-copper material is its high density. It should be noted, though, that alternative materials have become available, which possess commensurate thermal expansion properties, yet are considerably lighter.

The demultiplexer, as described in the preceding paragraphs, is designed to accept X-band incident signals over a 400-MHz-wide frequency span and partition them into four contiguous bands of 100-MHz width. The output port of each demultiplexer channel is connected directly to the input port of a MMIC downconverter chip. The HMC-130 GaAs-based chips [3], four in all, are commercial, off-the-shelf units, supplied by Hittite Microwave Corporation, Woburn, MA, and mounted with conductive epoxy on a low transverse ridge within the package. The MMIC format was chosen, in part, for convenience. More importantly, though, it was to demonstrate the use of MMIC's in a cryogenic environment. At liquid-nitrogen temperatures, charge carriers in semiconductors generally exhibit significantly higher mobilities than at room temperature. This can be utilized to attain notable performance advantages, especially with regard to active devices. In the case of the MMIC mixer circuits, though, it was not entirely clear how much improvement in conversion efficiency could be derived from cooling under given circumstances. There were obvious benefits to be obtained from reduced conductor losses at low temperatures, as well as from sharpened knee characteristics of mixer-diode current-voltage responses. But, to fully realize these benefits, it would have required either increasing local oscillation drive levels or biasing the mixer diodes in order to compensate for the shift in diode knee voltage with temperature. Neither option was practicable, due to constraints imposed by the parent project and the mixer design, respectively. The commercial MMIC chips, furthermore, had not been designed with low-temperature operation in mind, and there was no guarantee that all integrated components, including the delicate air-suspended spiral inductors, would hold up to temperature-induced stresses. Hence, prior to final selection, a representative chip was put through numerous consecutive cycles of dunking in liquid-nitrogen and rapid warm-up, with no failures observed. Electronically, the MMIC circuit, in its cryogenic state, also performed well. As shown in Section III, it exhibited a respectable 2–3-dB net improvement in conversion loss, when cooled to liquid-nitrogen temperatures.

The local oscillation signals for the downconverters derive from two external, fixed-frequency generators. The generator frequencies are selected to fall between nonadjacent, symmetrically located channels, producing two upper-sideband and two lower-sideband intermediate-frequency responses. In-phase power splitters divide each generator signal among respective downconverters. The splitter networks are implemented in microstrip form on a soldered-down 0.010-inch-thick alumina substrate. Metal-film isolation resistors are used in the splitters to assure reliable cold-temperature operation.

Following downconversion, the channelized signals are demodulated in hybrid-integrated-circuit detectors housed inside the cooled receiver package. The detectors are of the voltage-doubler type and distinguish themselves through their reliance on AlGaAs heterostructure ramp diodes. Each detector contains two diodes that appear as a shunt-connected anti-parallel pair to the incident intermediate-frequency signal and as a series-connected pair to the demodulated signal. The diodes are biased for optimum sensitivity in the vicinities of the current-voltage knees in their static characteristics. The bias currents are supplied from a package-external voltage source through a resistor network.

Rectification in AlGaAs heterostructure ramp diodes is achieved by having electrons encounter regions within the semiconductor material where the Al concentration undergoes abrupt changes [4]. To implement such a region, the Al concentration is gradually ramped from zero to some predetermined maximum value and then made to drop abruptly back down to zero across a single atomic layer. Maximum Al concentrations are determined by the application and typically run between 20% and 50%. Additional design freedom is provided by the ability to tailor diode response characteristics by stacking multiple alloy ramps on top of each other. The potential barrier established by each alloy ramp performs, thereby, in a manner analogous to a metal-semiconductor interface. The diodes employed in the receiver are of single-ramp construction, implemented as 100-μm-diameter passivated mesas from epitaxial material with 25% maximum Al content graded over a distance of 1000 Å. Fabrication of the diodes was performed at the University of Virginia, using material designed and grown at the Naval Research Laboratory.

Among the special attributes of heterostructure ramp diodes are their robustness and high-burnout capabilities. Although these attributes were not considered critical in the present context, ramp diodes do perform especially well at cryogenic temperatures. The receiver experiment thus presented itself as a convenient opportunity to demonstrate the new devices and test their reliability under stringent space-based conditions. The four detector circuits are contained on three 0.010-inch-thick alumina substrates, one of which also holds the two in-phase power splitters for the local oscillation signals mentioned earlier. The substrates, which appear in the photograph of Fig. 2 as contiguous light-colored areas, were soldered in place with the same type of indium solder employed for the YBCO-coated MgO substrate pieces.

III. Experimental Results

The exploratory nature of the channelized receiver and the general inaccessibility of the circuitry in its cooled environment made it necessary to assemble the receiver in stages and check out assembled components at each major step of the way. The first and most critical component to be implemented was the superconducting demultiplexer. For the purpose of confirming performance characteristics, it would have been desirable to have had direct access to individual channel output ports from outside the package, thus requiring four separate 50-Ω transmission-line connections to package-external ports. Spacial constraints and topological considerations prevented such connections to be included as permanent parts of the receiver design. The use of signal distribution networks in the form of temporarily mounted substitution circuits also did not appear as a practicable option. The concern was that the additional soldering operations involved in the substitution process would have placed the integrity of the six-piece demultiplexer assembly at risk. During reconfiguration, the soldered-down demultiplexer segments would invariably have been refloated, allowing the pieces to shift against each other and compromise performance. The adopted procedure, consequently, was to utilize the 50-Ω local-oscillation feeder lines as temporary output conduits for the demultiplexer channels under test.

Through the predetermined layout of the feeder structure, with its two integrated power splitters operating in reverse as power combiners, the demultiplexer's four channel output signals were grouped into pairs and recorded only as sums of two signals. Deembedding procedures, based on equivalent-circuit models of the feeder structure and the demultiplexer circuit, were then used to reconstruct the individual channel responses. The process was facilitated by the fact that paired signal channels were not contiguous, with overlap among channel responses confined to noncrucial stopband frequencies. The four channel characteristics obtained in this manner are depicted in Fig. 3. The underlying measurements of paired channel responses, which are also shown in Fig. 3, were performed at 77 K, with an incident-signal drive level of 0 dBm. To facilitate a direct comparison between the two sets of curves, a first-order 3-dB adjustment for power splitter attenuation was applied to the measured results. Observed minor discrepancies are largely due to circuit parasitics that had not been accounted for and to fabrication tolerances. The apparent trend for passband ripple to increase with decreasing channel center frequency is attributed to the cumulative effects of such tolerances, recognizing that lowest-frequency signal components had the farthest to travel along the demultiplexer trunk line. Also partially responsible for some of the minor aberrations are the finite accuracy of the applied deembedding

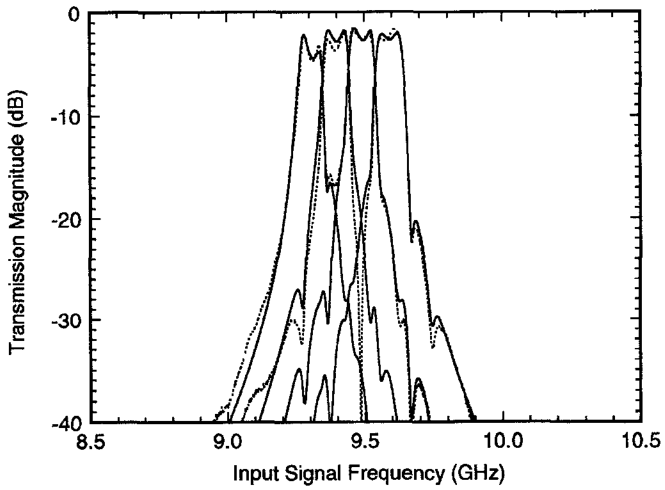

Fig. 3. Demultiplexer response characteristics: Reconstructed channel responses (————), and measured responses of channel pairs (- - - - -).

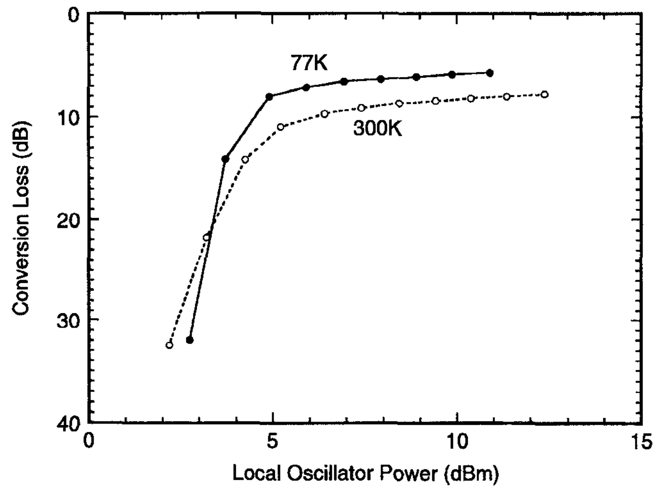

Fig. 4. Performance of the HMC 130 mixer chips, measured at 77 K (————) and at room temperature (- - - - -).

process and the effects of discontinuities associated with 0.1-inch-long 50-Ω transmission line pieces used to connect, in lieu of the downconverter chips, the demultiplexer output ports to the feeder structure. These pieces were small enough to be held in place with conductive epoxy, thereby circumventing the refloat issue and allowing for their easy subsequent removal. The depicted responses are believed to represent the first measurements to be reported on a successful superconducting microwave channelizer of direct-coupled manifold design. The results confirm the effectiveness of the arrangement, as evidenced by the low values of signal attenuation at passband and crossover frequencies.

The next set of receiver components to be installed in the package were the mixer chips. With the 50-Ω local-oscillation feeder lines now employed as originally intended, the only access to the downconverter output ports, for testing purposes, was through high-impedance lines earmarked as parts of the detector circuits. The somewhat obscured information acquired in this manner provided adequate reassurance against the possibility of a defective chip, but did not permit a full assessment of intermediate-frequency channel response characteristics. A separate mixer chip, mounted in a three-port 50-Ω-based test fixture of its own was thus relied on to establish confidence in the viability of the chips at low temperatures. As alluded to earlier, both the mechanical integrity of the test chip and its epoxy-based attachment emerged unimpaired from exposure to large and rapid swings in temperature. Conversion efficiency numbers, all the while, remained consistent, while indicating a 2–3-dB performance advantage at 77 K over room-temperature operation. This is illustrated in Fig. 4, where the mixer's response characteristics are plotted as functions of local oscillator drive level for temperatures of 300 and 77 K, respectively. The drive level of the 10-GHz incident signal was set at 0 dBm, producing a 100-MHz intermediate-frequency signal, with the local-oscillation frequency kept at 10.1 GHz.

Prior to equipping the receiver with heterostructure ramp diode detectors, a prototype version of such a detector was assembled and tested at cryogenic temperatures as an autonomous unit. This step was necessary to verify theoretical

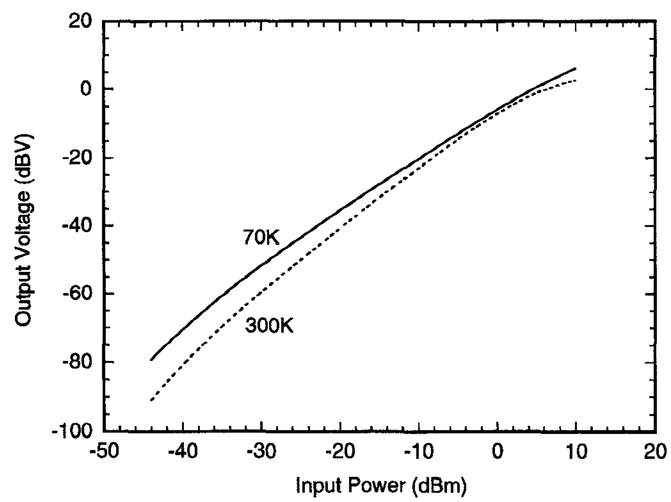

Fig. 5. Normalized response characteristics of a representative heterostructure ramp diode detector, measured at 70 K (————) and 300 K (- - - - -).

predictions of low-temperature diode behavior and to empirically determine bias conditions for achieving maximum detector sensitivity. Representative response characteristics for the prototype detector circuit are given in Fig. 5, acquired at 300 K and 70 K with the heterostructure ramp diodes biased in series at 0 and 50 μA, respectively. For these measurements, the circuit was fed at the input from a 100-MHz variable-power 50-Ω-referenced signal source and terminated at the output in an effective 5.6-kΩ load presented to the detector circuit by the direct-coupled resistive voltage divider used for biasing.

With confidence in the ramp diode technology established, four copies of the prototype detector circuit were added to the receiver assembly, serving as a convenient interface with the payload measurement equipment, in accordance with earlier-mentioned objectives. The only change made to the prototype design was the inclusion of a shunt-connected 10 pF capacitor and a shunt-connected 50-Ω ballast resistor at the input to each detector. The purpose of the ballast resistors was to reduce

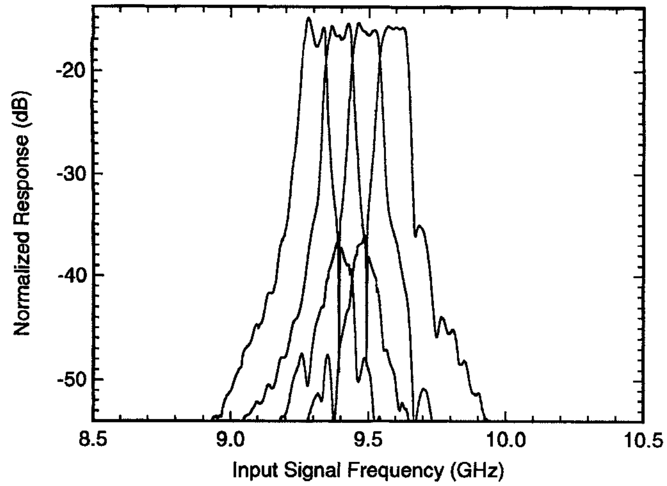

Fig. 6. Normalized channel output voltages of the cryogenic channelized receiver measured as functions of frequency for an incident signal drive level of 0 dBm.

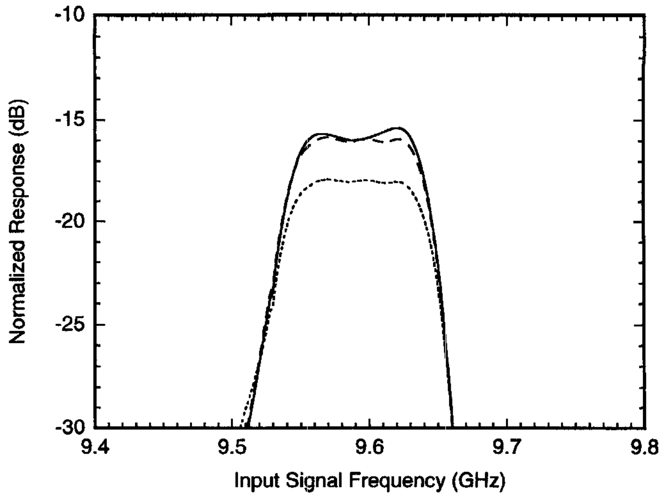

Fig. 7. Normalized output voltage response of the fourth channel as a function of incident signal drive level: −10 dBm (————), 0 dBm (– – – – – –), and +10 dBm (- - - - - -).

the sensitivity of channel responses to mixer intermediate-frequency terminations, albeit with some degradation in signal strength. The response characteristics thus obtained for the completed four-channel receiver unit operating at 77 K are summarized in Fig. 6. The plots depict individually measured channel output voltages as functions of frequency, which occur in response to an incident swept-frequency signal supplied from a square-wave-amplitude-modulated high-frequency source. With the detectors operating in their square-law regimes, the recorded voltages are directly proportional to detected signal power levels. The responses, consequently, have been plotted on a dB scale as ten times the logarithm of receiver sensitivity, given as output RMS voltage per mW of incident power and divided by an arbitrary reference detector sensitivity of 1 V per 1 mW, thereby allowing convenient comparison with the demultiplexer response curves shown in Fig. 3.

Although receiver performance was affected, to some extent, by the presence of the downconverters and the limited bandwidths of the employed detector circuits, channel responses remained predominantly determined by the frequency-selective properties of the demultiplexer. The plots in Fig. 6 thus depict, in essence, the behaviors of second-order channel filters whose passband-to-stopband transitions have been sharpened as a result of network conditions provided by the direct-coupled manifold architecture. The observed tendency for passband ripple to increase with decreasing channel center frequencies remains largely attributed to the effects of fabrication tolerances and residual, uncontrolled parasitics related to the demultiplexer, as discussed in connection with Fig. 3, compounded by the effects of signal reflections off the input ports of the mixer chips that had not been compensated for in the design. No attempt was made to correct for aberrations by way of post-fabrication adjustments.

In order to gauge receiver saturation behavior, the channel responses were also recorded as functions of incident signal level. Representative curves for one of the channels, plotted against expanded magnitude and frequency scales, are provided in Fig. 7. All measurements were performed with 12 dBm of local oscillator power supplied to each mixer chip at frequencies of 9.4 and 9.5 GHz, respectively. The channel responses exhibited noticeable amplitude compression as incident signal levels were allowed to approach +10 dBm. The power-dependent results offer only a cumulative assessment of nonlinearity contributions from the demultiplexer, the mixers, and the detector circuits. To identify contributions on an individual basis, power-dependence measurements would have been required for each receiver component type separately. Such measurements were forced to give way to an aggressive time schedule imposed by the parent project. Nevertheless, experiences with earlier prototype component versions indicate that all three main segments of the channelized receiver were involved to comparable degrees in determining power dependence of receiver transfer characteristics.

The electromagnetic fields associated with a strip of superconductor material, when in the superconducting state, are confined to a very thin layer near the surface of the material. Induced currents, resulting from the response of Cooper pairs to external fields, screen the interior of the superconductor. The depth to which the screening currents penetrate into the material is determined by the Cooper pair density. As the temperature is raised toward the transition temperature, the Cooper pair density decreases rapidly, leading to a corresponding increase in penetration depth. From a circuit standpoint, the internal magnetic fields and Cooper pair currents manifest themselves as an added inductance term that, in turn, gives rise to a measurable decrease in the phase velocity for a signal propagating along a guided-wave structure. The phenomenon is commonly referred to as the kinetic inductance effect. For quality high temperature superconductor films that possess narrow transitions and that are employed at temperatures low enough to encounter only residual quasiparticle losses, kinetic inductance effects can be unobtrusive. Nevertheless, in circuits that have pronounced frequency selectivity, such as the channelized receiver presented herein, even relatively small perturbations can be quite significant.

To adequately account for kinetic inductance effects, equivalent-circuit-type models are needed. Although kinetic inductance effects in planar transmission lines have been successfully modeled using approximate boundary condition techniques [5], accurate circuit-oriented descriptions, which were being developed concurrently, were not available for the design of the receiver's demultiplexer. They were subsequently employed, however, in calculating the demultiplexer's de-embedded response characteristics shown in Fig. 3. Channel center frequencies were thereby permitted to shift slightly away from nominal values. Considering the proof-of-concept nature of the project, this was deemed acceptable, since designated channel frequencies were all expected to shift in a synchronous manner, which indeed proved to be the case.

IV. Conclusion

The objective of the HTSSE-II parent project has been to prove the merits of high temperature superconductor technology in high-frequency system applications, subject to the rigorous constraints of space deployment. Consequently, in addition to demonstrating a practicable concept, each contributed experiment had to accommodate stringent payload restrictions on size, weight, prime power consumption, and thermal load on the spacecraft's cooling system, as well as withstand compulsory shock and vibration treatment. Experiments were selected so as to cover a range of diverse applications. The intent of the channelized receiver has been to demonstrate how superconductor technology can be combined with other disciplines to derive compounded benefits from operating in a common cryogenic environment.

Among the auxiliary technologies employed in the receiver are those associated with the MMIC and hybrid-integrated-circuit formats chosen for implementing mixer and detector functions, respectively. The main focus, though, has been on the superconducting front-end of the receiver, comprising an X-band demultiplexer of direct-coupled manifold construction with four contiguous, 100-MHz-wide channels. Direct-coupled manifold configurations hold significant advantages over alternative realizations with regard to compactness, but are noted for their lack of isolation among channel filter input ports. Although the design frustrations that normally result therefrom were successfully sidestepped with the help of an approach based on modified logarithmic-periodic principles, the interdependence among channel-designated subcircuits, from which essential selectivity benefits were derived, remained preserved.

Within the context of the described investigation, the demultiplexer's interchannel dependencies served a supplementary diagnostic function by allowing fabrication tolerances of one circuit element to potentially affect the responses of more than just one channel, with a tendency thus to render aberrations more visible. The challenge has been successfully countered, as illustrated by the observed regularity of the four measured channel responses. The results are tempered only by a general awareness of issues such as material costs, cooling requirements, and nonlinearities—issues common to superconducting thin-film realizations of high-Q microwave filter structures. Helped by these constraints, a general preference remains for alternative technologies in the form of miniaturized dielectric resonator approaches and active filter techniques. There are distinct niches, however, where superconductor-based solutions have advantages. Receiver front-end situations, like those encountered in channelized receivers, comprise just one suggested area of application.

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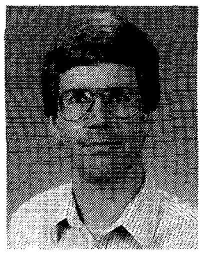
From 1969 to 1976 he was employed as an Assistant and Research Associate at the Microwave Laboratory of the Swiss Federal Institute of Technology, where he conducted research on computer-aided tolerance optimization of microwave active circuits and on IMPATT power amplifiers. He held an international fellowship from the Swiss National Science Foundation from 1976 to 1978, studying the nonlinear behavior of GaAs field-effect transistors at Cornell University, Ithaca, NY, and at the Naval Research Laboratory, Washington, DC. Subsequently, he joined the Naval Research Laboratory as a Member of the Technical Staff, where he currently heads the Solid-State Circuits Section. On sabbatical leave from 1985 to 1986, he investigated the application of high-speed photoconductor technology to the on-chip characterization of microwave monolithic circuits and millimeterwave devices at the Los Alamos National Laboratory, Los Alamos, NM. His present research interests involve active and passive high-frequency circuits of all kinds, with emphasis on the derivation of novel microwave filter concepts and on the exploitation of nonlinear signal interaction in semiconductor devices at microwave, millimeterwave, and optical frequencies.

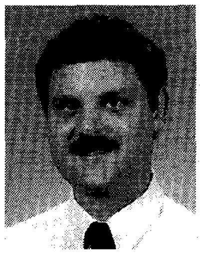
Dr. Rauscher was the recipient of the 1987 IEEE Microwave Prize for his work on microwave distributed active filters as well as the recipient of the 1991 NRL Sigma Xi Applied Science Award from the Scientific Research Society of America.



Jeffrey M. Pond (S'82–M'82) was born in South Haven, MI, on April 10, 1956. He received the B.S. degree in electrical engineering from Michigan State University, East Lansing, in 1978 and the M.S. and Ph.D. degrees in electrical engineering from the University of Michigan, Ann Arbor, in 1979 and 1982, respectively, where he was a Research Assistant in the Radiation Laboratory.

He has been with the U.S. Naval Research Laboratory in Washington, DC from 1982 until the present. His research interests are on the application of new materials to microwave devices and circuits. Recently, his efforts have been focused on the application of high temperature superconductors for microwave circuits and systems and the development of thin-film ferroelectric microwave device concepts.

Dr. Pond has served on the Technical Program Committee for the annual IEEE International Microwave Symposium since 1992.



Gregory B. Tait (S'83–M'84–SM'96) was born in Holyoke, MA, in 1960. He received the B.A. degree in physics from Amherst College, Amherst, MA, in 1982, the M.S. degree in electrical engineering from the University of Maryland, College Park, in 1984, and the Ph.D. degree in electrical engineering from The Johns Hopkins University, Baltimore, MD, in 1991.

From 1982 to 1986, he was a Member of the Technical Staff in the Advanced Communications Department at Fairchild Communications and Electronics Company, Germantown, MD. From 1986 to 1994, he conducted research at the Microwave Technology Branch of the Electronics Science and Technology Division, Naval Research Laboratory, Washington, DC. Additionally, he served as an Adjunct Faculty Member of the Department of Electrical Engineering at the University of Virginia, Charlottesville, VA, from 1992 to 1994. In 1994, he joined the faculty of the Department of Electrical Engineering and Computer Science at the United States Military Academy, West Point, NY. His current research interests include photonic semiconductor devices and nonlinear microwave circuits.

Dr. Tait is a member of Phi Beta Kappa, Sigma Xi, URSI Commission D, and the American Physical Society.