Guest Editorial

THE Nobel-prize-winning discovery in 1987 of cuprate-based superconductors, which led to materials such as YBCO with transition temperatures above that of liquid nitrogen, sparked a worldwide research and development effort. Four years later, this special issue shows that the first applications of high-temperature superconductors are in filters and antennas. The 19 papers came from four different countries. Many of the components described in this issue will be tested in the Navy's High-Temperature Superconductivity Space Experiment, scheduled for launch in late 1992 [1] (Fig. 1). This experiment should demonstrate that this new technology is sufficiently robust to survive the space environment and can significantly improve electronic systems.

Filters and resonators are the most important applications, as evidenced by the eight papers in this section. The first paper demonstrates a 77 K, 10 GHz multipole filter with a 150 MHz passband (1.2% bandwidth) and a 1.0 dB insertion loss. Also shown is the ability to design filters to specification with current materials technology, e.g. YBCO on $LaAlO_3$ substrates. These filters, which have a higher Q and a lower insertion loss than copper, are expected to have near-term applications in preselector (front end) filter banks. Coplanar, multipole low-pass filters are described in the second paper. This approach uses a single film on one surface of the substrate and offers cost and processing advantages. The performance of thallium-based films with a higher T_c (102 K) than YBCO (90 K) and with a measured surface resistance one tenth that of copper at 20 GHz is described in the third paper. A 5 GHz microstrip resonator at 90 K exhibited a small degradation in Q with input power up to 10 W. Coplanar resonators are described in the fourth paper, together with measurements of RF surface resistance. The next paper describes several passive microwave devices fabricated with thallium-based films. A 35 GHz resonator is described, together with a band-reject filter and a band-pass filter. Ring resonators fabricated from laser-ablated YBCO films are described in the sixth paper, with performance data at 35 GHz. Next to last in this section is a report of the measured performance of a three-pole E-plane filter constructed from high-T_c bulk material operating at 34.5 GHz. Several superconducting waveguide filter configurations are also discussed. The paper closing this section reports the first experimental demonstration of a quasi-optical frequency selective surface filter using YBCO films on MgO and $LaAlO_3$ substrates. This investigation was made over the frequency range of 75 to 110 GHz.

Three papers describe the advantages of superconducting antennas. An invited paper by Dinger, Bowling, and Martin gives a survey of possible applications from 1 MHz to 100 GHz. Preliminary experiments show YBCO and TBCCO superconducting thin-film antenna and matching networks to be more efficient than copper at 500 MHz. The second review paper states that the main advantage of superconductors lies in decreasing the matching network losses. Higher-gain millimeter-wave arrays can be realized with superconducting passive distribution networks. The third paper describes a 2.4 GHz microstrip antenna that has been miniaturized by a new "stepped impedance" patch shape and high substrate permittivity. Radiation efficiency of the antenna is better with YBCO than with copper.

Resonators are used to measure the surface impedance of thin YBCO and TBCCO films as well as their high-power properties. In the first paper in the section dealing with film property measurements, the overtones of a 1.5 GHz microstrip cavity are used to determine the frequency dependence of the surface resistance of YBCO. At low temperatures, the surface resistance of YBCO shows weak dependence on the RF magnetic field up to 225 Oe. The surface resistance of the best YBCO film measured at 10 GHz is 85 $\mu\Omega$ at 4 K and 200 $\mu\Omega$ at 77 K. The second paper describes a dielectric-rod-loaded resonator useful for measuring the impedance of YBCO samples of relatively small diameter below 20 GHz. In the third paper, the surface resistance of TBCCO films is measured at 18 GHz with copper and niobium cylindrical resonators. The best surface resistance values are 4 and 14 mΩ at 10 K and 77 K respectively; corresponding copper values are 8 and 21 mΩ. Typically, the surface resistance begins to rise in 1–10 Oe of microwave field and saturates in 20–60 Oe. Films exhibiting the highest degree of orientation show the weakest dependence on power and exhibit the sharpest temperature-dependent transition to the superconducting state.

The three papers of the theoretical section treat the electrodynamics of superconductors in terms of a two-fluid model consisting of normal and superconducting electrons. The first paper of this section shows how an imperfect superconductor can be treated as a dielectric material of negative dielectric constant. The two-fluid model is applied to stripline, microstrip, and coplanar transmission lines in the second and third papers.

The two papers in the final section describe devices made with the more mature, low-T_c niobium technology. A superconducting niobium chirp filter in the first paper has a dispersive time delay of 26 ns over an impressive 3.4 GHz bandwidth centered at 4.7 GHz. In the second paper a sapphire-loaded niobium cavity, having a Q of several hundred million, is useful both as a parametric transducer for a resonant bar gravitational wave antenna and as an ultra-low-phase-noise oscillator. Niobium and niobium ni-

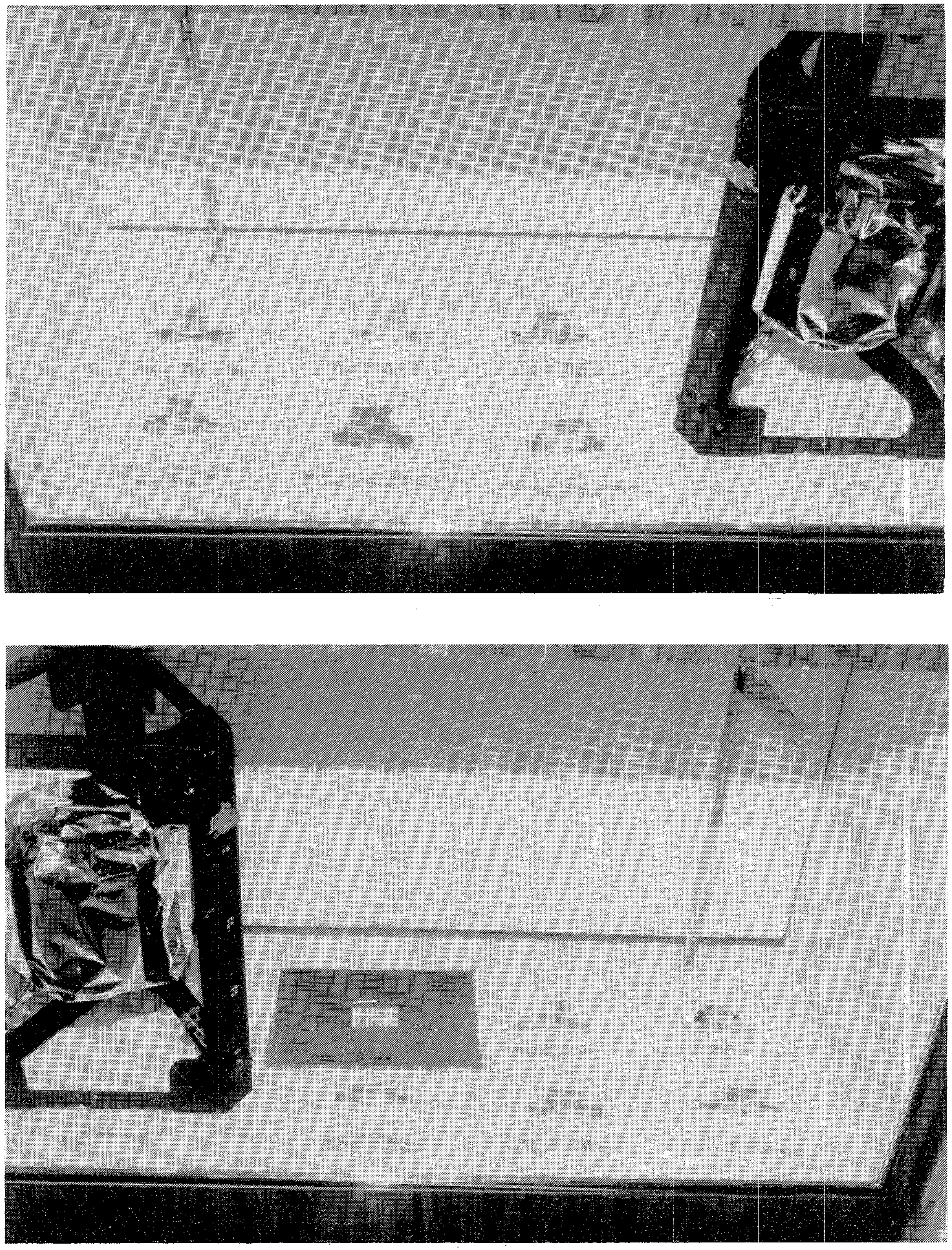

Fig. 1. High-temperature (77 K) superconducting passive microwave devices selected for satellite flight test are shown here with a mock-up of the cyropackage that will contain them. This program, the first of its kind, is sponsored by the Naval Research Laboratory (photographs courtesy of the Steering Committee of the 1991 MTT-S International Microwave Symposium, Boston, MA).

tride technology has advantages in ultra-low-noise communications receivers and ultra-wide-bandwidth radars in the 100 to 1000 GHz band [2].

At present the loss in most high-temperature YBCO and TBCCO films is not as low as that in niobium. As the relatively young high-temperature, thin-film superconductor technology matures, the theoretical loss at 77 K, which is predicted to be comparable to that of niobium at 4.2 K, should be achievable. Niobium passive devices will then be replaced by high-T_c devices with their lower refrigeration costs.

This special issue would not have been possible without the contributions of the many authors and the time and expertise of the reviewers. We wish to thank them as well as Dr. Stephen Maas, TRANSACTIONS Editor, and Chris Ralston, copy editor at IEEE Headquarters.

REFERENCES

[1] M. Nisenoff, D. U. Gubser, S. A. Wolf, J. C. Ritter, G. E. Price, "High-Temperature Superconductivity Space Experiment: Passive Millimeter Wave Devices" SPIE, vol. 1394, *Progress in High-Temperature Superconducting Transistors and Other Devices* (Santa Clara, CA), 4–5 October 1990, p. 104.

[2] D. Hayes, "The potential of superconductive electronics for EHF SATCOM terminal technologies," in *Proc. IEEE Military Commun. Conf.* (San Diego, CA), Oct. 23–26, 1988.

PAUL H. CARR
BRUCE R. MCAVOY
Guest Editors

Paul H. Carr (SM'68–F'79) received the B.S. and M.S. degrees in physics from the Massachusetts Institute of Technology, Cambridge, in 1957 and 1961, respectively, and the Ph.D. degree in physics from the Brandeis University, Waltham, MA, in 1966.

He is currently Chief of the Components Technology Branch, Electromagnetics Directorate, Rome Laboratory (formerly Rome Air Development Center and Air Force Cambridge Research Laboratories), Hanscom Air Force Base, MA. He directs in-house and contractual research and development of microwave components using high-temperature superconductors and monolithic microwave/millimeter-wave integrated circuits.

Dr. Carr received the Marcus D. O'Day Memorial Award for the best AFCRL paper published in a scientific journal in 1967 and the 1973 Guenter Loeser Memorial Award for sustained scientific achievement in AFCRL. In 1976, he won an Air Force Systems Command Outstanding Technical Achievement of the Quarter Award for the development of a low spurious SAW delay line for a radar system. Dr. Carr has been active in the IEEE, serving as chairman of the Boston Section on Microwave Theory and Techniques (1989–1990) and on the Technical Program Committee of the Ultrasonics Symposium (1971–1989), of which he was chairman in 1976. He also served on the Technical Program Committee for the Microwave and Millimeterwave Monolithic Circuits Symposium (1986–1988). Dr. Carr is a member of the American Physical Society and the DoD Advisory Group on Electron Devices. He has published more than 70 papers and is the holder of eight patents.

Bruce R. McAvoy (SM'68–F'88) received the B.S. degree in physics from the University of Rochester in 1954, with further studies and teaching experience at Carnegie-Mellon University.

He has had extensive experience at the Westinghouse Science and Technology Center in developing microwave components for radar applications, starting in 1957 with solid-state research and continuing to microwave acoustic devices for signal processing and frequency control. More recently he has been involved with the development of high-T_c microwave filters and resonators. He has published extensively in these fields and holds 11 patents.

In 1983 Mr. McAvoy was awarded the Westinghouse Engineering Achievement Award and in 1990 a Westinghouse Signature Award of Excellence. He is a member of MTT-18, Microwave Superconductor Applications, and chairman of MTT-2, Microwave Acoustics. He has served on the technical program committees for the International Microwave Symposium and the Ultrasonics Symposium and is on the Editorial Board of the IEEE MICROWAVE AND GUIDED WAVE LETTERS. He was the recipient of an IEEE Centennial Medal.