than the random errors! It depends on the power spectrum of the errors. For a white power spectrum, as for shot noise, the low-pass filtering action of a moving average reduces the noise power in proportion to the bandwidth, and so the root-mean-square noise decreases in proportion to the square root of the bandwidth reduction. Those systematic errors that were referred have their power spectra concentrated near dc and so do not get reduced by low-pass filtering. On the other hand, systematic errors, particularly in the case of quantization noise, can sometimes be concentrated deliberately up near the Nyquist frequency and so become almost completely excluded by low-pass filtering. This opportunity has been known for a long time. The introduction of ordered dither of the signal with respect to quantization levels, whether it be accomplished open-loop or by closed-loop feedback, as with delta–sigma data converters,[1] does the trick.

A rare counterexample to Murphy's law led to my awareness of the possibility. My measurements with a sensitive tiltmeter[2] looked to be much cleaner than expected. After publication I found that laser intensity ripple coupled with a small imbalance of the three-port homodyne mixer to give the dither by sheer accident. A check of the noise power spectrum showed that the noise was mainly near the Nyquist frequency, so that subsequent filtering removed most of it. The result was that the noise became reduced by much more than the square root of the bandwidth reduction and ended up probably less than a picoradian at a kilohertz bandwidth, close to the shot noise limit.

Simple examples are Wilkinson (single-slope) and successive-approximation analog–digital converters, where the resolving powers increase linearly and exponentially with bandwidth, respectively. More incisive examples are the oversampling converters used in audio compact discs. The physics community could profitably exploit the vastly improved trade-off relationships to reach the very sensitive measurements sought by LIGO, the Laser Interferometer Gravitational Wave Observatory.

References

1. See J. C. Candy, G. C. Temes, *Oversampling Delta–Sigma Data Converters*, IEEE P., New York (1992), for an extensive review.
2. L. N. Mertz, Rev. Sci. Instrum. **62**, 1356 (1991).

LAWRENCE N. MERTZ
Palo Alto, California

7/92

The quip by Daniel Kleppner's friend about the seductive perils of statistical analysis brings to mind the cautionary words of Ernest Rutherford: "If an experiment requires statistical analysis to establish a result, then one should do a better experiment."

RICHARD PETRASSO
Massachusetts Institute of Technology
Cambridge, Massachusetts

7/92

Antenna Array Amount Amendment

We very much regret that in our article "The Search for Forming Planetary Systems" (April, page 22), the number of antennas planned for the Berkeley–Illinois–Maryland array at Hat Creek in the California Cascade Mountains was incorrect. The relevant sentence should have stated that within a year BIMA will have nine 6-meter telescopes.

ANNEILA I. SARGENT
California Institute of Technology
Pasadena, California
STEVEN V. W. BECKWITH
Max Planck Institute for Astronomy
Heidelberg, Germany

5/93

DOD Acting Research Director's Past Actions

I appreciate the complimentary write-up by my good friend Irwin Goodwin of my appointment as acting director of research and laboratory management at the Department of Defense (October 1992, page 108). My mother would have loved it. Permit me to make just two corrections. First, I could never have turned out the three Defense Critical Technologies Plans "virtually single-handedly": They were truly a team effort by many dedicated scientists and engineers at DOD, and I was fortunate to have had their support and cooperation. Second, as to my future responsibilities, they are unknown. I shall endeavor to serve in whatever capacity I can be most useful in bringing science and technology to the service of my country.

LEO YOUNG
Department of Defense
Washington, DC

10/92

Must Scientists Help Define a 'Better World'?

In his Opinion column "Physicists in the 'Age of Diminished Expectations' " (March 1992, page 61), Arthur Kantrowitz demonstrates trust in the progress offered through modern physics and encourages the scientific community to seek ways in which it might "restore our faith in the potential of science-based technology" while helping us resist those who seek a "risk-free," more cautious society.

We need continued technological advances, especially when they promise potential solutions to societal needs, but the seriousness of the problems that technology creates are today of equal concern. Kantrowitz worries about the decline of American productivity and raises the question, "How can physicists help in restoring the hope . . . of Americans that their children would live in a better world?" but he fails to consider what is meant by the idea of a better world, and that there are competing visions of what that world may look like. Technology and the national economy are not the only dimensions in which human progress is properly measured. Yet rather than asking physicists to consider issues of socioethical import, of what true progress for ourselves and our world might be, Kantrowitz demands that physicists do a better PR job within the growing competition "for control of the public perception of scientific findings." Surely the *a priori* question is, What are the reasons for the loss of confidence in science and technology?

Why is it that today more diseases are curable and more lives saved, and yet a steady erosion of trust in MDs continues? Doctors have been trained to be objective technicians without training in compassion and care. Placebo tests demonstrate the place of nurture in effective healing, and enough alienated voices demonstrate the need for a change in medical training, yet our trust in technology to the exclusion of wider human values and needs continues.

Are we to continue, too, with the assumption that everything our technology creates will be for the good? Or, if anything perilous is developed, that the peril will yield to further technological solutions? Surely our hope for a better society needs to be based on a vision of the good rather than on the narrow ideal of technological progress. The idea of an objective and amoral science's developing complex technologies while leaving instrumental decisions in other hands is Orwellian. The genius of technology is that it can be used to create or destroy, and its power is now so great that we cannot but ask ethical questions of its advance. This is not to lay responsibility solely at the scientists'