(available in English translation from Artech House, Norwood, Massachusetts), however, describes a number of techniques for jamming monopulse systems, including frequency modulation of the jamming signal. Other U.S. technologies to resist jamming or detection come under the category known generally as "low probability of intercept." They include the use of "low sidelobe" or narrow-beam antennas and spread-spectrum or frequency-hopping transmission.

All of these countermeasures and counter-countermeasures are expensive. For example, the Air Force canceled a proposed upgrade of a jammer pod, known as Seek Ram, when costs escalated to $3 million each—with a total program cost of $2 billion. One of the requirements that drove up the cost was deceptive angle-jamming of monopulse radars.

Some of the counter-countermeasures impose problems of their own as well. One disadvantage of frequency hopping is that it vastly complicates the signal processing requirements for Doppler radar. Doppler radar, which measures the speed of a target by the frequency change of the echoed signal, is especially useful in cluttered environments, such as that presented by a low-flying aircraft when seen from above. So-called look-down shoot-down radars use the Doppler technology; no one has yet developed a frequency-hopping version. The Navy's Aegis system, which is a frequency-hopping radar, does not have a Doppler capability—which means that it can't see sea-skimming targets such as low-flying cruise missiles against the clutter of surface waves.

The most ambitious solution to the problem of radar vulnerability is to put the radar transmitter out of harm's way entirely. At normal radar frequencies, the signal is propagated only along line of sight, limiting the distance that the transmitter can stand off. But at much lower frequencies—around the short-wave broadcast bands—signals can bounce off the ionosphere. Over-the-horizon radar takes advantage of this principle to look thousands of miles away. The United States is now building a network of 12 over-the-horizon Doppler radars around Alaska and the U.S. continental rim as part of the modernization of the strategic early warning system. One general disadvantage, however, is that resolution is poor. Although the system can detect a low-flying bomber or cruise missile from long distances, it cannot determine where the object is within about a 5- or 10-mile block.

Another way to keep the radar off the battlefield is through bistatic operation—placing the radar transmitter and receiver on separate platforms. Loral, which makes the ground-mapping synthetic aperture radar for the highly classified SR-71 spy planes, has reportedly test-flown a bistatic system. The Air Force is also studying the idea of placing radar transmitters on satellites. "In fact the transmitter might even be one of theirs," says one government expert. Although such "noncooperative" illumination is beyond the state of the art for now, it is under study as the ultimate in concealed signals. One difficulty is that the relative locations of the transmitter and receiver have to be known very precisely—to within a wavelength or less.

One interesting feature of this very expensive option is that it may undo another very expensive option, namely, stealth. Stealth designs aim to reduce the reflectance in the direction the beam would be coming from. But "it's basically impossible to make it invisible from all directions," says one expert.

For most military applications, it is unlikely that the near future will see either a markedly reduced reliance on radar or any of these expensive high-tech fixes. Tom Amlie, a long-time Pentagon critic of radar, says that the inevitable result will be a growing vulnerability of U.S. forces. "No sane infantryman would run to the top of a hill, put a flare on his helmet, and dare the enemy to hit him," he says. "Yet radar systems do the electronic equivalent of exactly that." ■

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UC Told to Review Impact of Research

The University of California must set up a review process to ensure that federally funded agricultural research primarily benefits small farmers, the California Superior Court ruled on 17 November. The decision, if upheld, in effect requires the university, which has the largest academic research budget nationwide, to weigh the social costs of innovation to small farmers. The university says it will appeal the decision.

The judgment culminates a lawsuit filed nearly 8 years ago that challenged the legality of spending public research funds to develop labor-saving machinery, including the tomato harvester (*Science*, 30 March 1984, p. 1368). The lawsuit was brought by a group of farm workers and families who own small farms. They assert that mechanization displaces farm workers and drives smaller farmers out of business. The university has argued that the lawsuit threatens academic freedom to pursue research.

Representatives of the farm groups hailed the decision. Debra Jones, executive director of the California Action Network, said in a statement that the ruling "will impact all types of agricultural research, including biotechnology and pesticide development."

But the decision, handed down by Judge Raymond Marsh of Alameda Superior Court, is narrower than it could have been. The ruling applies only to small farms, not farm workers, "who were the original consideration," says William Hoerger, a lawyer for California Rural Legal Assistance, "so that's a disappointment." Ironically, the California Grange, which represents many of the state's small farmers, sided with the university in its defense.

Marsh ruled that the university violated a century-old federal law that says the interests of the family farmers shall be given "primary consideration" by agricultural research projects funded by the federal government. The law, the 1887 Hatch Act, establishes and funds agricultural experiment stations across the country. The university, Marsh stated, "has no process designed to ensure consideration" of small farmers.

Hatch funds account for $4 million or 3% of the university's total agricultural research program, but this money is distributed widely. Hoerger estimates that Hatch funds help support as much as three-quarters of the school's 1400 agricultural projects, so the ruling could have a broad impact.

Marsh ordered the university to submit to the court in 90 days its plans for administrative procedures to weigh the impact of agricultural research projects on small farmers. The university will seek a stay of the order because it plans to appeal, said Christine Helwick, a university attorney.

The problem with the judge's order, Helwick said, is that he "asks us to predict the downstream effect of research and requires that it impacts the right group. It becomes a political guessing game to predict the impact of research and who it is going to hurt."

She said that the university regarded the outcome as "a great victory because the plaintiffs lost or gave up many of the original claims." She noted that the judge did not explicitly say that the university's research was indeed harming small farmers, only that it did not have in place a process to review the effects. But Helwick conceded that if the decision is upheld, it will have a substantial effect on the university's agricultural research. ■ **MARJORIE SUN**