called "integral operator" to a speech signal. This mathematical process takes all the bumps and sudden shifts out of the original waveform. "What comes out is a smoothly varying signal," Walter says. "On an oscilloscope, it doesn't look at all like the original speech signal."

To recover the original speech, the message's authorized receiver applies a differential operator – the inverse of the integral operator – to the encrypted signal, which restores its initial choppiness. However, certain integral operators may fail to hide information adequately. The human ear is remarkably resilient, Walter says. "If we aren't careful about the way we choose the integral operator, [an eavesdropper] can still understand what comes through."

Moreover, the overwhelming preponderance of digital equipment in the modern laboratory stymies the testing of analog cryptographic devices. "The problem is that we have to simulate these analog devices by digital means [on a computer], which sort of defeats the purpose," Walter says.

Nevertheless, Davida adds, "we've achieved some remarkable results in the realm of both [information] compression and encryption."

A newer, alternative approach to analog cryptography involves dividing an analog signal into small pieces, then using a relatively new mathematical technique known as wavelet analysis to break each piece up into its components. The idea is that any wave segment can be represented by a suitable collection of fundamental building blocks, or wavelets.

The wavelet technique converts each wave segment into a set of numbers representing how many of each building block are present in the given segment. Scrambling these numbers produces a new, different waveform, which can then be sent as an encrypted message. The receiver, who knows how the numbers were scrambled and which set of wavelets were used as the building blocks, reverses the process to hear the message.

One advantage of using wavelet analysis for cryptography is that the process simultaneously shuffles frequencies and times. The scheme changes not only the order in which pieces of the wave are transmitted but also mixes up the signal's characteristic frequencies.

"I'm really anxious to try this method in the laboratory," Walter says. "I think we can simulate it on a computer."

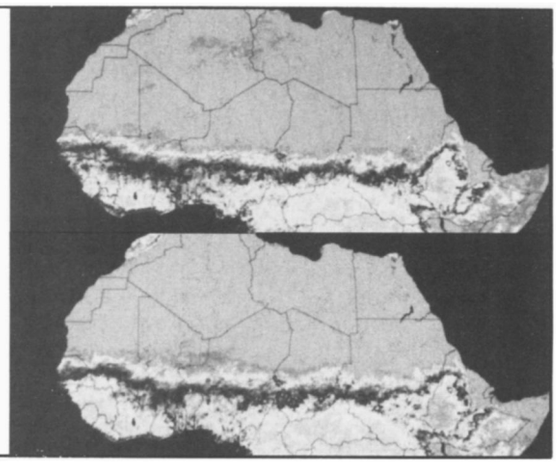
"We feel rather lonely because not many people are working in this area," Davida says. "I think they have mistakenly abandoned analog systems. I can't imagine analog signals going away entirely."

Furthermore, analog cryptographic systems may help lower the cost of assuring privacy, Davida says. "It's worthwhile to have privacy available to anyone who wants it." *– I. Peterson*

Satellites expose myth of marching Sahara

The expansion of the Sahara desert appears a dramatic example of an environmental crisis: Pictures in the media show towns buried under sand dunes that engulf more and more arable land each year. But satellite measurements over the last decade reveal the march of the Sahara – the largest desert on Earth – is not as widespread or severe as the United Nations and other organizations had supposed.

Reports in the 1970s and 1980s portrayed the southern edge of the Sahara rolling ever southward like a wave, expanding into the sub-Saharan Sahel region at a rate of 5 kilometers per year. International organizations laid much of the blame for this "desertification" on overgrazing and other land use problems.



Satellite measurements of north Africa show bands of vegetation shifting north or south in response to rainfall changes. From 1984 (top) to 1985 (bottom) the vegetation moved northward 110 kilometers, reducing the size of the Sahara desert by 724,000 square kilometers.

NASA

But vegetation measurements collected every day by U.S. meteorological satellites show that the southern edge of the Sahara ebbed and flowed more like a tide over an 11-year period starting in 1980. Compton J. Tucker and Wilbur W. Newcomb of NASA's Goddard Space Flight Center in Greenbelt, Md., and Harold E. Dregne of Texas Tech University in Lubbock report the observation in the July 19 SCIENCE.

"The message [of these results] is that a lot of what's been claimed about the so-called desertification of the Sahel is just incorrect," says Sharon E. Nicholson, a meteorologist at Florida State University in Tallahassee, who has studied rainfall patterns in Africa.

Previous reports of desert expansion have erred by assuming that trends observed in a few isolated locations were occurring across the entire continent, says Tucker. They also failed to take into account the effect of a drought that plagued the region during the 1970s and 1980s, causing vegetation patterns to shift, he adds.

Meteorological satellites, however, now allow broad regional tracking of the desert's boundary, which Tucker's group defines as the area that receives 200 millimeters of rainfall per year. The scientists gauged precipitation amounts indirectly from the amount of red light reflected off Earth's surface. Because chlorophyll in plants absorbs red light, desert areas reflect more red light than do vegetated regions. Areas of thicker plants correspond to areas that receive greater amounts of rainfall.

The boundary between the arid Sahara and the semi-arid Sahel region migrated appreciably each year during the study period. From 1980 to 1984, the desert expanded southward, with the boundary shifting 240 kilometers (km). But from 1984 to 1985, the trend reversed and the divider moved north by 110 km in a single year. It moved northward another 30 km the next year. In 1987, the boundary shifted back southward by 55 km, and northward 100 km in 1988. In 1989 and 1990, it shifted southward 77 km.

While the southern extent of the Sahara in 1990 reached 130 km further south than in 1980, that difference does not reflect a long term trend but rather a difference in the year-to-year rainfall, Tucker says. The results suggest researchers will have to measure over a number of decades in order to discern any long-term changes due to human activities, he contends.

During the last decade, reports of desert expansion in the Sahara prompted development programs to provide substantial funds for planting and irrigating rows of trees – an expensive effort designed to stabilize sand dunes. But these agencies are now shifting their focus, in part because of the satellite measurements. "This is the first time that we have had a broad overview of the desert boundary issue," says Ridley Nelson, an agricultural economist with the World Bank in Washington, D.C. Development organizations see desert advancement as less of a problem and are instead addressing practices that lower the productivity of dry land areas, Nelson says.

– R. Monastersky