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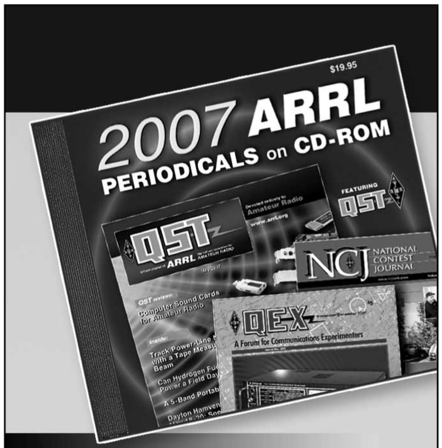

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A Look at NVIS Techniques

DX communication isn't *always* what we want when we send radio waves up toward the ionosphere. Sometimes we want the solid regional communication afforded by *near-vertical-incidence skywave*—a highly reliable MF/HF communication technique that may already be part of an emergency plan near you.

By Ed Farmer, PE, AA6ZM
839 Shoreside Dr
Sacramento, CA 95831

It seems like almost every HF-antenna construction article by radio amateurs concludes with tales of improved DX—so often that we may assume that the value of an MF or HF antenna depends entirely on how *far* it lets us communicate. The assumption seems to be that DX—long-distance communication, for whatever purpose—is the sole desired communication type at MF and HF.

But we don't *always* want long-distance communication when we use our MF (1.8 MHz—160 meter) and HF (3.5 MHz [80/75 meter] and up) bands. We may want only *regional* communication—say, to roundtable with our "buds" on 75 or 160 meters or to handle state and regional traffic, emergency or otherwise.

This article describes an MF/HF communication approach that intentionally limits, even avoids, DX capability. Called *near-vertical-incidence skywave*, its aim is providing reliable communication without the coverage loss that occurs in the *skip zone* (Figure 1) commonly encountered in DX communication.

NVIS (typically pronounced *neh*-viz) propagation isn't useful for DX, but if you need uniform, dependable, skip-zone-free coverage throughout an area with a radius of 400 miles or so, NVIS is your best bet.

Who cares about NVIS? In California, NVIS techniques are considered important by the Governor's Office of Emergency Services and the California State Guard. (The California State Guard ties the entire state together every week on their HF net using NVIS techniques.) The California Division of Forestry is investigating NVIS systems for fire line communication out of narrow mountain canyons. NVIS is an integral part of current US Army and Marine Corps communication doctrine.

NVIS Basics

Radio communication at MF and HF depends on the ionosphere's ability to bend signals back to Earth. Whether a signal can bend back to Earth at the angle necessary to link two given locations depends on a number of factors, including the ionosphere's ability to bend the signal, the frequency in use, and the angle at which the signal enters the ionosphere.

The angle at which a signal enters the ionosphere, relative to a line perpendicular to the ionosphere, is its *angle of incidence* (Figure 2). What's special about NVIS communication is that, unlike DX communication, it operates with angles of incidence of less than 45°. As a result, NVIS signals return to Earth relatively close to the transmitter. Because NVIS operation exhibits no skip zone, continuous coverage is possible from the transmitting antenna right on out to the farthest point at which the NVIS signal returns to Earth.

The highest frequency at which a wave aimed straight up reflects back down is

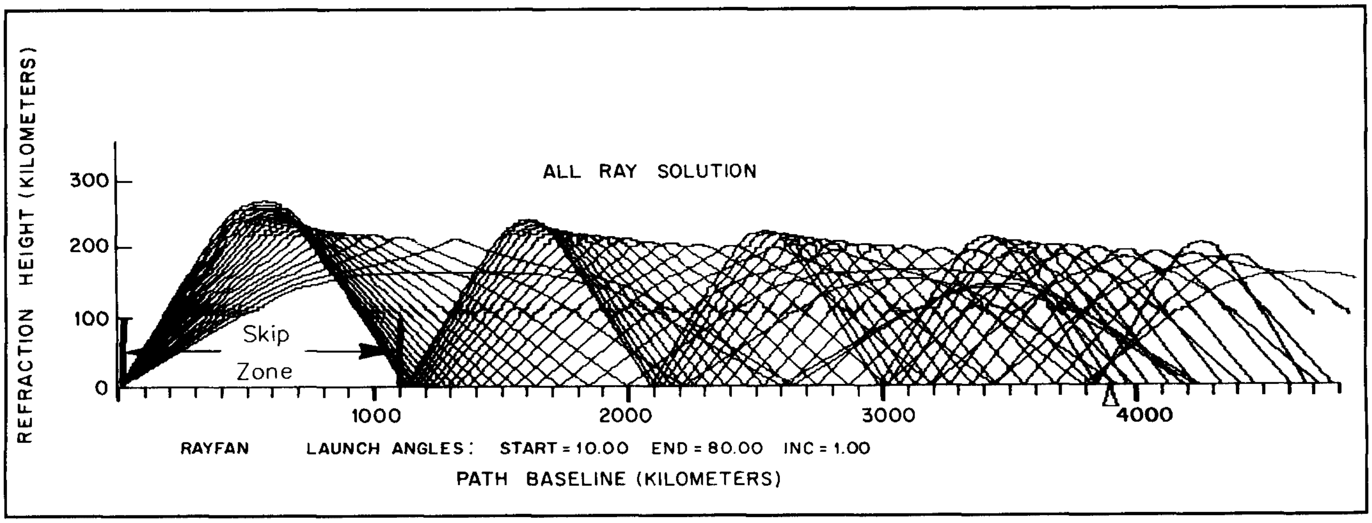

Figure 1—A *skip zone* occurs in ionospheric communication when the ionosphere fails to return to Earth radio energy transmitted at high angles relative to Earth. This skip-zone illustration (for a 14-MHz path, and encompassing takeoff angles from 10° to 80° in 1° increments) is simplistic because it does not include the contributions of ground-wave and scatter propagation, but these effects do little to offset the skip zone's "no-coverage" character. (Adapted from the *Advanced PROPHET* ray trace graphics, which appeared courtesy of the Naval Ocean Systems Center, San Diego, in Figure 5, Chapter 22, of the 1994 *ARRL Handbook for Radio Amateurs*.)

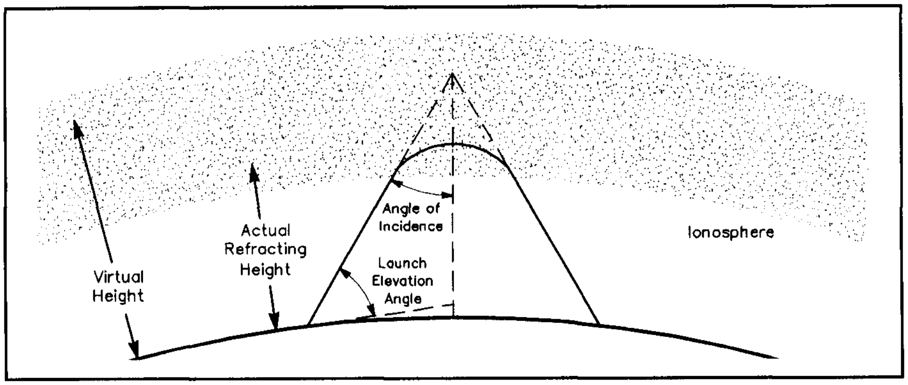

Figure 2—A radio wave that encounters the ionosphere exactly head-on—perpendicularly—is said to exhibit an *angle of incidence* of 0°. Near-vertical-incidence skywave communication makes use of the fact that signals sent just about straight up come back just about straight down. Proper system planning can harness this effect for highly reliable, skip-zone-free communication in Amateur Radio's MF and lower HF bands. (This drawing, which also appears as Figure 21.7 in the 1995 *ARRL Handbook*, also shows the difference between angle of incidence and launch elevation angle or *takeoff* angle. When we say that a DX antenna exhibits "good low-angle radiation," we're talking about its takeoff angle.)

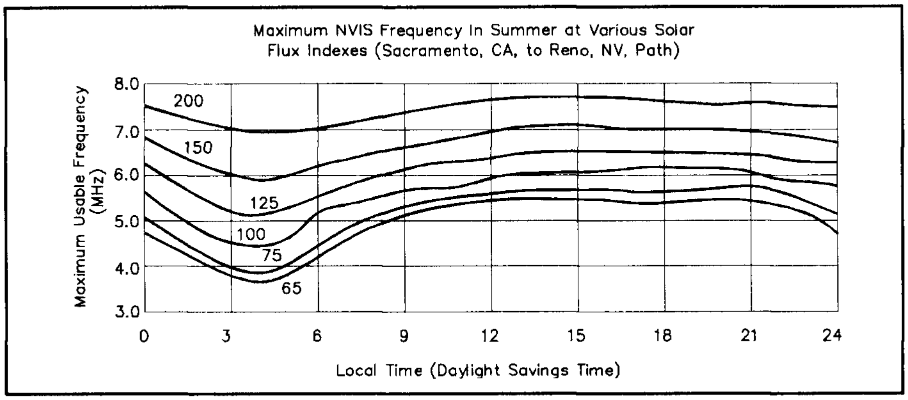

Figure 3—How the summer MUF varies with solar flux for the Sacramento-Reno NVIS path.

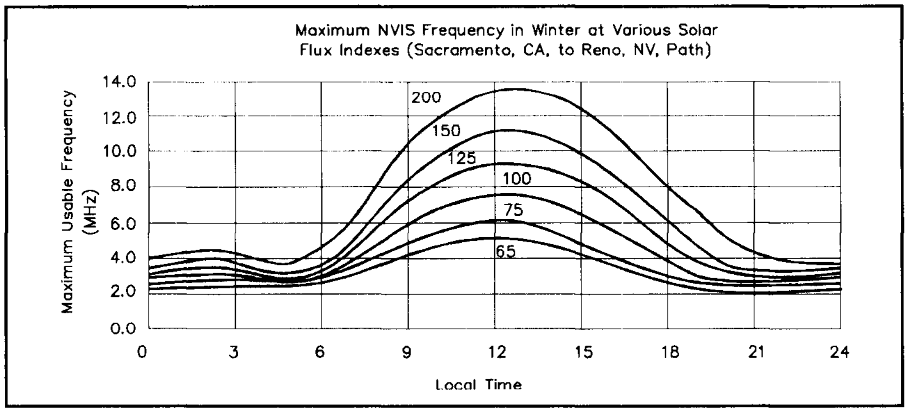

Figure 4—How the winter NVIS MUF varies with solar flux for the Sacramento-Reno NVIS path.

called the *critical frequency*. Successful NVIS communication requires that we operate below the critical frequency, but as close to it as practically possible.

Critical frequency is an apt term. Operating close to a system's limit runs the risk that at least some of the time, things will not work out as planned. Operating at the critical frequency is no exception to this. The ionosphere refracts HF and MF radio signals because it contains particles that have been ionized—electrically charged—by solar radiation. The ionosphere's refractive ability therefore varies with the Earth's night/day cycle, with the seasons, and as solar activity varies over the solar or sunspot cycle. The critical frequency for a given path therefore varies continuously over time.

Reliable NVIS communication allows for critical-frequency variations by operating at a frequency somewhat lower than critical. Doing so involves a trade-off, however. As we move down in frequency, *absorption*—signal loss due to ionospheric inefficiency—increases. The trick in selecting an NVIS operating frequency is to use the highest frequency that provides dependable communication. On any given day, there is no way other than experimenting to fine-tune this. Commercial and military radios equipped with automatic link establishment (ALE) do this testing (called *sounding*) automatically.

Selecting an NVIS Frequency

First, we must determine the critical frequency. To do that, we need to know the time of day, the time of year, and the current solar activity. A computer program (*MINIPROP*, for example[1]) can make this otherwise very tedious task quite simple. Such programs calculate the maximum usable frequency (MUF) between two locations.

MINIPROP and other programs capable of doing this require the position (latitude and longitude) for you (Terminal A, *terminal* being propagation-speak for a station at one end of a communication link) and your intended point of contact (Terminal B). For NVIS purposes, enter your location for Terminal A and any location near you for Terminal B.

The last number you need is some measure of solar activity. This can be the sunspot number or *solar flux index* (*SFI*). You can obtain the solar flux index by listening to WWV (2.5, 5, 10, 15 and 20 MHz) at 18 minutes past each hour, or WWVH (5, 10 and 15 MHz) at 45 minutes past each hour. (On WWV and WWVH, it's called just *solar flux*.) Enter the SFI, and the program should quickly show you the critical frequency throughout the day for your intended communication path.

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[1] The sidebar on pp 21.18-21.19 of the 1995 *ARRL Handbook*, "MUF Prediction on the Home Computer," overviews the features, attributes and availability of the propagation prediction programs *ASAPS*, *IONCAP*, *IONSOUND*, *MINIMUF*, *MINIPROP PLUS* and *CAPMAN*. Availability information is also available by writing PROPPRGM.TXT, Technical Information Service, ARRL, 225 Main St, Newington CT 06111 USA. The file PROPPRGM.TXT is also available electronically: from the ARRL BBS at 203-666-0578, or by e-mailing the message:
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to the Internet address *info@arrl.org*.

Figure 3 shows typical summer NVIS MUF values at various solar-flux levels. Figure 4 shows NVIS MUF values for the same path on a winter day.

At our present position in the solar cycle, solar-flux index values are well below 100 with values of 65 to 85 being common. At SFI values this low, the critical frequency is lower than 7 MHz most of the time, so 40-meter NVIS operation will pretty much be out. On the other hand, the critical frequency is well above 4 MHz during the day, making 80/75 meters our best choice for daytime NVIS communication. (Because 500 kHz represents a significant percentage-of-frequency change in this part of the spectrum, NVIS signal levels at the high end of the band—75 meters—will likely be somewhat better, since daytime absorption will be slightly less at 4 MHz than at 3.5 MHz.)

At current solar-flux values, especially in winter, the nighttime critical frequency between closely spaced terminals is so low that use of the 160-meter band becomes essential.

Under better conditions (higher solar flux indexes), a rule of thumb could be 40 meters during the day and 80 meters at night. At low solar-flux indexes, though, this approach usually won't work. Keep in mind that *skip-zone-free* coverage is usually a goal of NVIS systems. When the solar flux is low, you might be able to use 40 meters to talk to someone hundreds of miles away, but it just won't work for someone dozens of miles away. Stations that close will be in the skip zone.

Choosing a viable frequency is only part of the challenge of ham-band NVIS. During the daytime, signal absorption and local noise make obtaining a useful signal-to-noise ratio a challenge. At night, as absorption decreases with the setting sun, propagated noise and band congestion become the limiting factors.

NVIS Antennas

With any antenna, we are mainly concerned about two things:

1) Does the radiation go where we need it? (pattern)

2) How much of the transmitter's power makes it into space? (efficiency)

A desirable NVIS pattern is one in which most of the radiation is upward—at takeoff angles greater than 45°. Doug DeMaw, W1FB, aptly referred to these as "cloud warmer" antennas. Figure 5 shows the pattern for a dipole 1/8 λ above ground—most of its radiation is above 45°, and there is very little at the low angles useful for DX. This antenna puts the signal where it's needed, and when,receiving, attenuates DX signals that would otherwise be QRM.

What happens as the dipole is raised? Its low-angle radiation increases at the expense of high-angle radiation. Above about 0.2 to 0.3 λ, NVIS performance begins to suffer.

From what I've said about antenna height so far, you might think that the lower the antenna, the better. Mounting an antenna close to the ground takes advantage of ground reflection but increases its interaction with Earth and ground-mounted objects. Performance declines. Figure 6 shows the vertical gain (in dBi) of a horizontal dipole at various heights over average ground. Below 0.1 λ, the vertical gain drops off rapidly.

In addition to ground interaction, the same efficiency issues we consider in any antenna design apply, including resistive losses and feed line losses.

All this talk about the theoretical benefits of mounting heights in the vicinity of 0.2 λ eventually runs into the hard wall of practicality, especially in portable installations. In the 7-MHz band, a very manageable 30-foot mast will get us up near 0.2 λ. In the 75-meter band, this 30-foot mast would reach only to 0.13 λ, but as Figure 6 shows, performance will still be good. But at 1.9 MHz, 0.2 λ is nearly 100 feet! Our 30-foot mast is only 0.06 λ, for which we pay a vertical gain penalty of about 5 dB. But if we mounted antennas for all three bands at 100 feet (to optimize performance at 160 meters), we would *not* have NVIS antennas at 40 or 75 meters. Keep this and Figure 6 in mind when selecting mounting heights.

Antenna Selection

There are many antennas that are excellent for NVIS purposes. The primary ingredient is a horizontal radiating element located, in terms of wavelengths, fairly close to the ground. Avoid antennas with vertical radiating sections.

Balanced Antennas

The horizontal dipole, inverted **V** and **V** are the mainstays of NVIS systems. At NVIS heights, a **V** or inverted **V** will perform the same as a dipole at a slightly lower height. Keep them as flat as possible. Not only do these antennas perform well, but they're also easy to carry and simple to erect.

Changing the length of these antennas to keep them resonant as operating frequency changes between day and night is fairly simple: you add or subtract wire. If you get tired of doing this, you can install element wires for both frequencies and feed them in parallel from the same feed line. As long as you have an antenna tuner, you can also use a single dipole, not necessarily resonant at your operating frequencies, fed with low-loss feed line (such as ladder

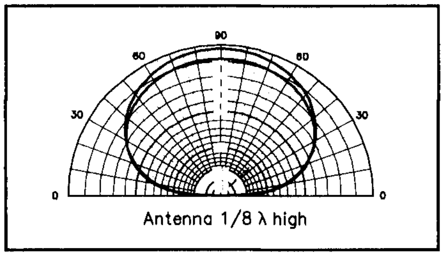

Figure 5—Rare is the Field Day group that hasn't discovered how well an antenna with this pattern—just a half-wave dipole 1/8 λ high—rakes in regional 75-meter QSOs on Sunday morning. We owe many of those QSOs to NVIS propagation. (The shaded region of this graph shows the dipole's pattern over average earth [k=13, G=0.005 siemens per meter]; the heavier curve shows the dipole's pattern over perfectly reflecting earth. For more on this and other dipole patterns at different heights, see Chapter 3 of *The ARRL Antenna Book*, 17th Edition.)

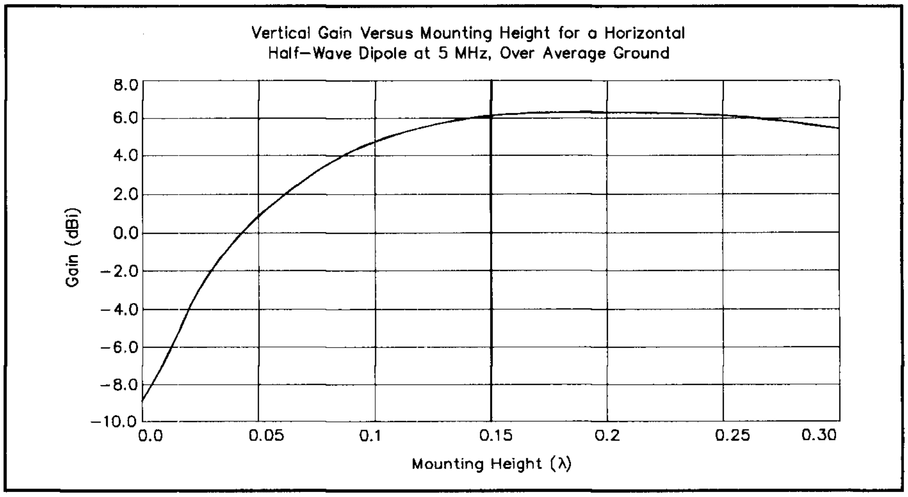

Figure 6—Lower is not always better for NVIS antennas. This graph shows how a dipole's vertical gain peaks near 0.2 λ, and then drops rapidly as its electrical height drops below 0.15 λ. (Modeled by the author with NEC-2.)

Why Use NVIS When We Have VHF/UHF and Repeaters?

Doesn't NVIS operation just duplicate what can be better achieved at much higher frequencies? Shouldn't we be handling local and regional communication at VHF—directly, or via one or more repeaters? The answer is *yes*—when VHF and repeaters can guarantee the communication that NVIS allows.

As well-developed as repeater systems can be, they're vulnerable to catastrophe. You and your hand-held can jump into the breach as long as your local repeaters stay alive, but what happens to that H-T's communication value when your local machines go down and *stay* down? Ah—your repeater gurus will fix them? What happens in a large-scale disaster—say, an earthquake in a major metro area? What if the highway bridges between you and your machine are down? What if *the structure carrying your repeater* is down?

Even if repeaters stay up, the physics of VHF/UHF radio isn't always our pal when we're out in the sticks—sticks that cover high hills and low valleys, sticks that can and do *burn*. Maybe you *can* hit that distant machine and get fire line relief—*if* you can somehow get up your H-T up that furnace of a slope to that ridge—or maybe you can't. In situations where VHF/UHF signals provide spotty to nonexistent coverage in hilly and mountainous terrain, MF/HF NVIS may well provide the solution.

Near-vertical-incidence skywave isn't on civil and military communicators' lips because it's trendy, or because repeaters and satellites are passé. It's there because the ionosphere may serve to port radio signals from Terminal A to Terminal B at times when repeating or transponding hardware can't, and when terrain disallows direct VHF/UHF contact. Just as the Chocolate-Coated Sugar Bombs advertised between Saturday morning's cartoons are "part of this balanced breakfast," increasing numbers of military and emergency communicators look to NVIS as "part of this balanced communication plan."

Radio amateurs have long had the frequencies, radios, transmitter power and antenna/propagation know-how to put NVIS techniques to useful work. What may seem like news is that frequencies capable of worldwide DX—particularly our bands at 1.8, 3.5 and 7 MHz—can be put to work in ways that simultaneously enhance regional communication while allowing their reuse farther away.

Now that you know about NVIS as a concept, you'll be better equipped to respond when emergency-preparedness officials ask about it. Better yet, you'll be able to suggest NVIS as an alternative when they don't.—*David Newkirk, WJ1Z, Senior Assistant Technical Editor*

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line). The antenna tuner resonates the antenna *and* the feed line together; hence, this is called a "resonant feed line antenna." As long as the antenna is balanced, the feed line does not radiate. (Walt Maxwell, W2DU, covers this in Chapter 20 of his book, *Reflections*.)

Arrays of horizontal active dipole elements, such as the Shirley Dipole, improve performance somewhat but are more trouble to erect. A parasitic reflector element under a NVIS dipole improves vertical radiation (especially over poor ground) with somewhat less installation trouble. Be sure the reflector is at least 5% longer than the dipole, or you may achieve the opposite of what you have in mind.

Loop Antennas

Vertically oriented small loops, such as the Patterson Loop (also known as the Army Loop) perform well. At NVIS frequencies, these "small" loops are fairly large, and transportation and assembly consequently requires some thought. The tuning of loops is sensitive to the movement of nearby objects, such as trucks on a fire line. Efficiency depends on minimizing the resistance of the loop, which requires special care at all joints that must be connected during field assembly.

Unbalanced Antennas

Actually, the term *unbalanced antenna* is an oxymoron (like the terms *government efficiency* and *military intelligence*). If you don't provide a "second half" for an antenna, it will make its own out of whatever is available, including the radio itself, the Earth under it, the microphone cord, and even the operator.

I have a strong preference for balanced antennas. Nonetheless, antennas used successfully in NVIS communication include the inverted **L** and random wire. The entire length of these antennas—from the connection point on the radio to the end of the wire—radiates. This means that the antenna begins near the ground and rises over a distance to some height. A portion of its length is horizontal and a portion is vertical. Getting the best performance requires adjusting the length and configuration so the highest antenna current is not in the vertical sections. Further, unless you are operating over very conductive ground, you'll have a choice between providing a "counterpoise" wire or getting RF burns on your lips on voice peaks. By the time you do this "right," it isn't much easier than erecting an inverted **V**, which will always perform better.

It's Not That Hard

Near-vertical-incidence skywave, an MF/HF technique that intentionally downplays DX work to achieve highly reliable local and regional communication, is well-established in military and governmental circles. Amateur Radio's 1.8, 3.5 and 7-MHz frequency allocations are aptly placed to provide good NVIS communication throughout the sunspot cycle. Readily available software and antenna texts can provide good system-design data for amateurs interested in getting started with NVIS. I hope this look into NVIS techniques encourages you to put your station's NVIS capability to work.

Ed Farmer was originally licensed in 1959 at age 13 as WL7DNZ (Novice) and became WA6SCI (Conditional) in 1960. He was inactive from about 1970 until 1990, when he took all the exams and became AA6ZM. He presently works DX (over 100 countries worked but only about 80 confirmed) and digital modes (such as RTTY, PacTOR and G-TOR.) He also holds a commercial General Radiotelephone license.

Ed holds a BSEE (1971) from California State University at Chico, where he also completed the Master's program in physics. His work has largely been in industrial control systems and communication systems, mainly for oil industry applications. He has published two books and many articles, holds four patents, and owns EFA Technologies Inc, the main product of which is a computer-based leak-detection system for oil and gas pipelines.

Ed has an interest in military communication and serves as a Major in the California State Military Reserve. Most of his work there involves radio communication planning and operations. Additionally, he does volunteer work for the Governor's Office of Emergency Services.

Strays

KENWOOD TO RESURRECT PRODUCTS?

◊ I was talking to someone at Kenwood technical support the other day concerning the IF-10B interface for the TS-940 HF transceiver. He said that Kenwood is thinking about remaking the IF-10B, and is discussing the pros and cons because of many phone calls for this product. He said it would help if people send letters or contact Kenwood about bringing back the IF-10B and other discontinued products. I also found out that the chips needed for the IF-10A/B and EPROMs are still available from East Coast Transistor Parts Inc. The tech at Kenwood said there's plenty of room inside the TS-940 to perfboard the interface and hardwire it into the rig. The chips and EPROM cost about $70.—*Ted Coats, NZ3Q, Philadelphia; Internet TedCoats@aol.com or tedcoats@ix.netcom.com*