Cosite interference: Force XXI communications roadblock

by David Fiedler

Along with our modern weapons systems' increased lethality and accuracy come an ever-increasing demand for highly mobile, survivable, redundant and complex voice- and data-communications systems. To keep up with the high mobility of modern weapons systems' platforms, the traditional command post at each echelon had to be mounted on various vehicles — ranging from a single "humvee" to larger shelter configurations mounted on tracked platforms, such as a multiple-launch rocket system chassis (Figure 32).

CP shelters of this type are often grouped in multishelter interconnected configurations to form large CP complexes capable of commanding and controlling extensive tactical operations. These modern mobile CPs have on board the communications and automation equipment necessary to perform their functions at each tactical level.

Figure 32. Command-post shelter mounted on multiple-launch rocket system chassis. Note single closely-spaced antennas.

Communications tangle

Communications equipment installed on each platform can include two to five single-channel ground and airborne radio system very-high-frequency frequency-hopping radios; a mobile-subscriber equipment mobile-subscriber radio terminal (also VHF and in the same band as SINCGARS); an interim high-frequency radio, usually the 20-watt AN/GRC-213 or 400-watt AN/GRC-193 HF radio; an enhanced position-location reporting system navigation/data radio; an ultra-high-frequency satellite-communications radio; and a Global Positioning System receiver.

Along with this communications equipment comes a variety of automation equipment that includes processors, printers, displays, power supplies, cables, associated communications-security equipment, local-area network equipment and a "forest" of closely located antennas to serve the radio-transmission equipment.

Because of the heavy concentration of electronic equipment in such a small area, low-level broadband radio-frequency energy (noise) — produced by a variety of sources, such as radio-transmissions harmonics, power supplies, local oscillators in receiving equipment, shelter lights or prime-mover ignition — is coupled into the antennas and other wiring of nearby (cosited) equipment. Normally the noise-energy level produced by these sources is at such a low level it's not noticed in a radio receiver, even a sensitive one, because it's not significant when compared to the normal receiver and atmospheric background noise. Unfortunately, in a modern CP — due to the communications and automation equipment's proximity — the noise level becomes far high than the normal background noise level so radio circuits deteriorate rapidly.

Strictly from the radio-receiver point of view, this undesired energy also gets to the receiver via coupling from control lines or power connections. This noise energy drastically reduces the signal-to-noise ratio so the receiver can't detect the desired signal, since it's lost in the high background noise-energy level. In many CP installations, the noise "floor" has been driven up so high by the undesired broadband energy that, to pass the receiver threshold and process a desired signal, transmitter power level must be increased or the distance between transmitter and receiver must be drastically reduced to get an acceptable S/N ratio.

Practically speaking, 50-watt radios such as SINCGARS that normally can function at distances of 35-40 kilometers when used by themselves will have their distances cut to as little as four to five kilometers, or less. This highly degrading effect on radio S/N ratio, and therefore planning distance produced by unwanted energy generated by other equipment, is what is termed "cosite interference."

Cosite interference

Cosite interference isn't new to the Army. In fact, it's been around ever since we first tried to place more than one radio at one location. In the past, however, the problem was reduced to manageable levels — primarily by techniques such as good frequency management, physical separation of antennas, power-level control, good grounding techniques and, in some cases, selective filtering and signal processing.

With SINCGARS' deployment, however, cosite interference can no longer be avoided through frequency management alone, since modern doctrine calls for frequency-hopping across a shared list of frequencies used by many radio nets. Frequency sharing in SINCGARS — coupled with MSE mobile-subscriber radio terminals also using the same frequency spectrum, and adding in the in-band harmonics of both HF and UHF equipment on-board a typical CP — virtually guarantees severely degraded communications performance due to high receiver noise-energy levels in all cosited radio equipment across the frequency spectrum.

To make matters even worse, we're now packing more and more equipment into smaller shelters and less-well-shielded soft-top vehicles to meet mobility requirements. The smaller the shelter, the closer the antennas are, and the closer the antennas are, the more likely they are to receive unwanted energy from surrounding radios when they are transmitting (and sometimes even when they aren't).

Remember, the antenna was designed to pick up signal energy in a desired band of radio frequencies, but it also will receive in-band unwanted noise, harmonics, etc., that come with it. Therefore the biggest source of unwanted S/N degrading RF energy in a radio is coming via the antenna and transmission line directly into the receiver's front end, where it can do the most damage.

Other significant sources of degrading receiver noise — such as RF energy conducted into the receiver circuits via power lines, control cables or chassis currents — make bad situations even worse and are often harder to find and correct.

The actual degree of cosite interference for a specific CP configuration will depend on many factors. The main ones are:

- The number of cosited transmitters;
- The transmitter output power level;
- The duty cycle of each transmitter;
- The hopset bandwidth (if hopping);
- The data rate;
- Antenna placement;
- Equipment shielding;
- Bonding; and
- Grounding.

Make no mistake, the best of reduction techniques won't restore cosited equipment back to a non-cosited performance level. However, it's possible to operate cosited equipment at a level that will provide a Force XXI CP with a degraded but functional capability.

If a particular CP has one system that's paramount and can't tolerate any communications degradation — for example, special-weapons fire control, chemical defense or air-traffic control — the only way to assure peak communications performance is to completely isolate the critical system from the rest of the CP or shut down every other system in the CP.

Problem example

To illustrate the cosite problem, let's take a large tracked CP carrier with typical test data and a typical equipment and antenna layout (Figure 33) and analyze it. This analysis assumes the use of a frequency-hopping antenna multicoupler capable of allowing four SINCGARS radios to operate through one broadband antenna (for example, OE-254 discone) mounted on a 30-foot mast. Verified test data shows that under these conditions:

- When any SINCGARS is transmitting at 50 watts, MSRT won't be able to establish a call into the MSE area communications system via its associated radio-access unit. A minimum antenna separation of 20 feet is required to overcome the SINCGARS-generated increase in background noise and to provide an acceptable S/N ratio at MSRT to allow data to be exchanged and a call to be established.
- If the MSRT-RAU link has been previously established (call-establishment data has been exchanged and connectivity completed), the established link will remain active. However, voice quality may be marginal and any data over the link will be tenuous (high bit-error rate).
- If SINCGARS transmitter power is reduced to four watts or less, MSRT will be able to establish a call and maintain acceptable voice quality under these conditions. Data

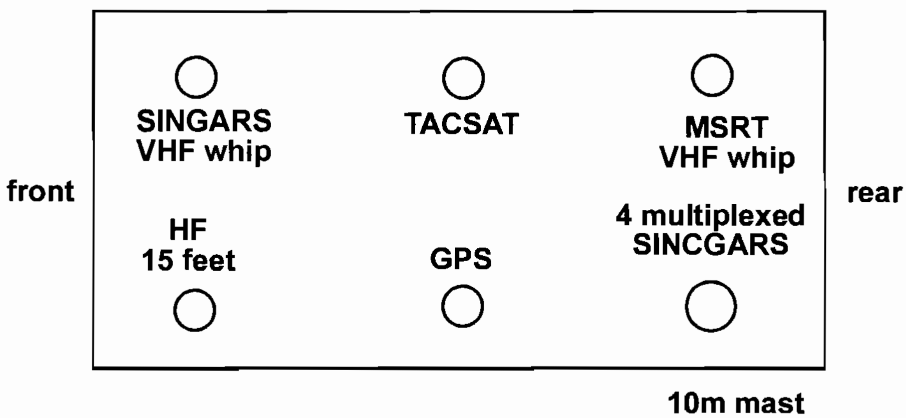

Figure 33. Sample antenna layout for large command-post tracked vehicles.

quality, however, may still be degraded. Tactically, the SINCGARS planning range will of course have to be reduced considerably as a result of both the lower transmitter power and MSRT's effect on the noise level when transmitting.

- If SINCGARS is configured to hop outside MSRT's receiver frequency range (59-88 megahertz outside the continental United States, or 40-50 mhz CONUS), plus a five-mhz "guard band" added, MSRT is relatively immune to cosite interference from SINCGARS. This is almost the equivalent of the old methods of reducing cosite interference by frequency separation; however, it removes large portions of available frequency spectrum and greatly restricts the equipment's capabilities.
- Full frequency range (30-88 mhz) full-power (50 watts) hopping transmissions from a cosited SINCGARS will reduce MSRT operational distances by up to 94 percent. MSRT transmissions (16 watts) will degrade a cosited SINCGARS operational distance by up to 74 percent. Effectively, full-power cosited operation of this equipment can render both systems inoperable in many tactical situations.
- Both interference and severe distance reductions to SINCGARS (more than 90 percent) can be expected when a cosited 400-watt AN/GRC-193 HF radio is transmitting. This is particularly severe when the HF transmitting frequency is harmonically related to the SINCGARS receive frequency.
- A similar severe reduction in operational distance and rise in interference levels can be expected in a cosited MSRT and AN/GRC-193, particularly when transmitting on a harmonic of an MSRT receive frequency.

Cosite fixes

Now that we know how badly the cosite situation can effect tactical communications, we must ask, "What can we as the Army's practical communicators do to make things work?" Fortunately there are answers that technically and tactically competent Signal leaders can use to improve the situation.

Some of these measures aren't elegant and will leave the Signal Corps open to criticism from other Army branches that use our services and equipment. As distasteful and embarrassing as it may be, the truth is that corporatively we didn't see the automation/data revolution coming to the tactical Army as fast as it did, and we weren't prepared with equipment or doctrine that would handle the mobile, small, electrically dense facilities our modern CPs have become.

Having said this, let's now examine some practical mitigation measures that may save some poor Signalman from the wrath of our combat-arms brothers in a tight situation. These measures may include:

- Reduce the number of interferers. Not every system is going to be carrying critical traffic all the time. Be prepared to shut down some less critical equipment when cosite interference becomes a problem. Signal officers must make clear to commanders that they must establish priorities for both systems and information so their minimum essential traffic can flow over remaining operational systems.
- Clever systems designs and operational work-arounds may sometimes be used to reduce system usage and thus reduce cosite interference. For example, nearby retransmission stations operating at full power can be keyed from a CP radio using a low-power transmitter to reduce cosite problems at the CP. The number of radio nets can be reduced by combining several low-usage nets into one. Stations can be separated on large nets by time, callsign/user address, terminal address and crypto key so several nets can use the same radio frequency, thus cutting cosite problems.

Note: operators should be careful when shutting equipment down to reduce cosite problems to make sure the equipment is truly off. Equipment left in an energized but quiescent standby mode can still radiate interference from control lines, equipment clock circuits, displays, local oscillators and other active circuits, which can produce almost as much interference as an active piece of equipment.

- Always use the lowest transmitter power possible consistent with maintaining operations. Since the Army first got radios, operators have traditionally tried to produce the maximum radiated power possible from the equipment. This was OK when a CP carrier had only two non-hopping radios and some telephones on board, but now the density is just too great.

For example, in a typical modern CP, going from 50 watts to four watts output power on a SINCGARS will reduce the interference energy received at cosited SINCGARS and MSRT antennas by 90 percent. This reduction in unwanted energy greatly reduces the effects of cosite interference on colocated radio receivers and is a great benefit to the voice or data system using the receiver. Unfortunately, to get some you have to give some, since the distance and area covered by the transmitting radio is now also reduced and operationally may not be acceptable.

- In a modern densely packed CP, don't frequency-hop unless someone holds a gun to your head. SINCGARS frequency-hopping was intended as an electronic countermeasure back in the 1970s, when the 10-foot-tall "evil empire" Soviet communicators were going to jam every tactical net we tried to establish. This situation no longer exists, if it ever did! Cosite interference and frequency-hopping are doing a better job of jamming CP communications than any fool with a jammer ever could (there are lots of ways to find and kill jammers if it's a problem). If reduced probability of detection/interception/location is the goal, modern Signal processing techniques will find your hopper anyway, so what's the point?

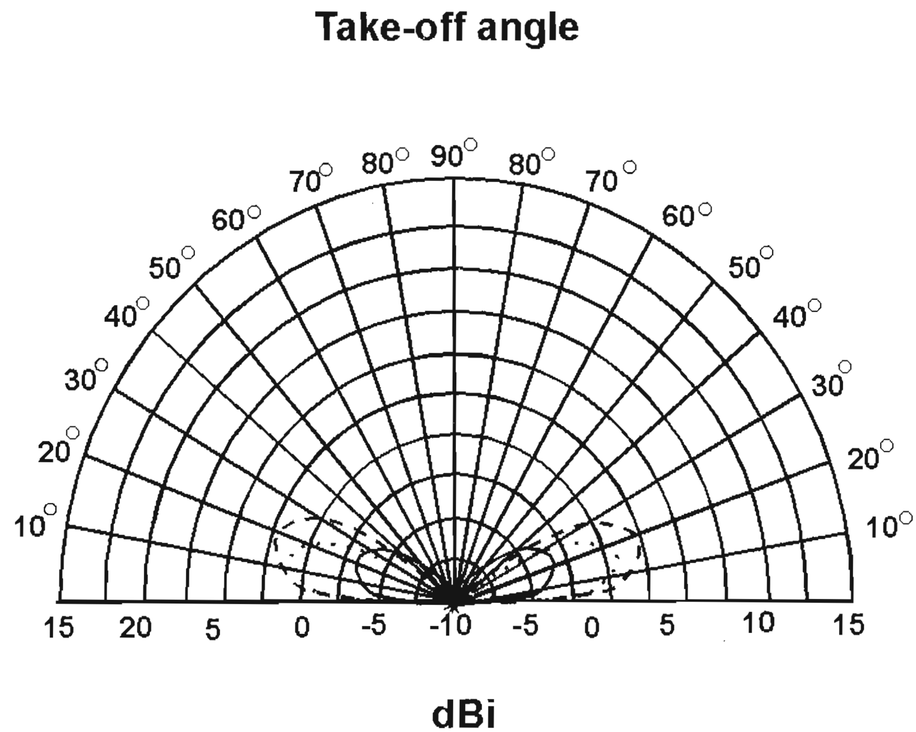

Figure 34. Whip-antenna pattern. Note energy null at high angles. Stack other antennas vertically in this null.

If you absolutely must frequency-hop for other reasons, your best bet is to constrain the SINCGARS frequency spectrum to 30-51 mhz. This is MSRT's transmit frequency band, plus a five-mhz "guard band" for added safety. This will protect cosited MSRT receivers from being swamped by SINCGARS-generated interference; however, it will reduce SINCGARS' antijam capability and frequency range. This frequency band should be further subdivided among SINCGARS nets to avoid interference between cosited SINCGARS.

By using constrained hopsets and classical single-frequency separation techniques, cosite problems can be greatly reduced but never completely eliminated. Never use broadband frequency hopping unless there's dome compelling reason, and then be prepared for drastic distance reductions, particularly in MSRT. Be very careful of harmonics, since no pre- or post-selection filters are provided in any of our equipment. Understand the technical characteristics of your equipment. Be sure the harmonics of one frequency hopset don't fall within the receiver frequencies of other equipment, or severe interference will result.

• Separate all antennas as much as possible, even if it means removing an antenna from a vehicle. Every inch counts, particularly on small soft-top type installations that don't use metal equipment shelters. The more separation between a transmitting antenna and a receiving one, the less destructive noise energy will be received. It's always best to use separate remote antennas for each equipment, even though this can reduce mobility and increase CP setup and teardown time.

Using directional antennas could also be a great help in reducing cosite interference if the tactical situation permits; however, there are no directional VHF antennas currently in the Army inventory, so you may have to construct or procure one on your own.

Varying vertical antenna heights will also help reduce cosite effects, since most antennas have "pattern nulls" where no energy is present (Figure 34). Placing a receive antenna in a transmitting null will reduce cosite problems, but placement may turn out to be a trial-and-error process. A field-strength meter will come in handy when looking for pattern nulls at a CP location.

Changing antenna polarization from vertical to horizontal for a few antennas at a CP (usually on systems where distance isn't critical) will also reduce coupling into cosited devices that remain with vertical polarization. Currently the Army has no horizontal VHF antenna in inventory, so you may have to make one of these, also. Horizontal HF antennas are available.

Stack antennas if possible. A look at Figure 34 shows that a vertical antenna has a deep energy null directly overhead when transmitting. A receiving antenna stacked in this null will receive much less interfering energy from a cosited transmitter. In the commercial/public service radio world, vertical-antenna stacking is a common practice to cut cosite interference. Just look atop any well-installed firehouse or police station to see what I mean. Again, standard Army equipment has no provisions for antenna stacking, so you'll have to use your own ideas.

• Be aware of grounding, bonding and shielding. Any current flowing in any conductor will radiate an electromagnetic field that changes at the frequency of the flowing current. If these conductors happen to be equipment power lines, control cables, ground connections, equipment cases and covers, they'll become antennas that radiate unwanted energy into other electronic equipment. In a modern Army CP, with its high density of sensitive communications and automation equipment, this energy enters the equipment usually by paths other than the radio antenna. Once within the equipment, the energy adds to the general background electronic noise level and level of cosite interference. This aspect of cosite interference is more insidious than the transmitter-caused cosite problem and is probably harder to find and fix.

To reduce these sources of cosite interference, the electrical bonds (contact) between equipment, its physical support structure and the earth must be good. Individual equipment and shelter grounds must be maintained well. Heavy braided-copper ground cables must be used to eliminate circulating currents that cause interference. The all-too-common poorly installed ground rod connected to a CP shelter with a thin cable and alligator clips should be grounds for court-martialing the Signal officer responsible. All cables, equipment cases and other equipment must be shielded, grounded and tested to prevent unwanted radio noise. This action alone in many CP configurations will reduce cosite interference measurably.

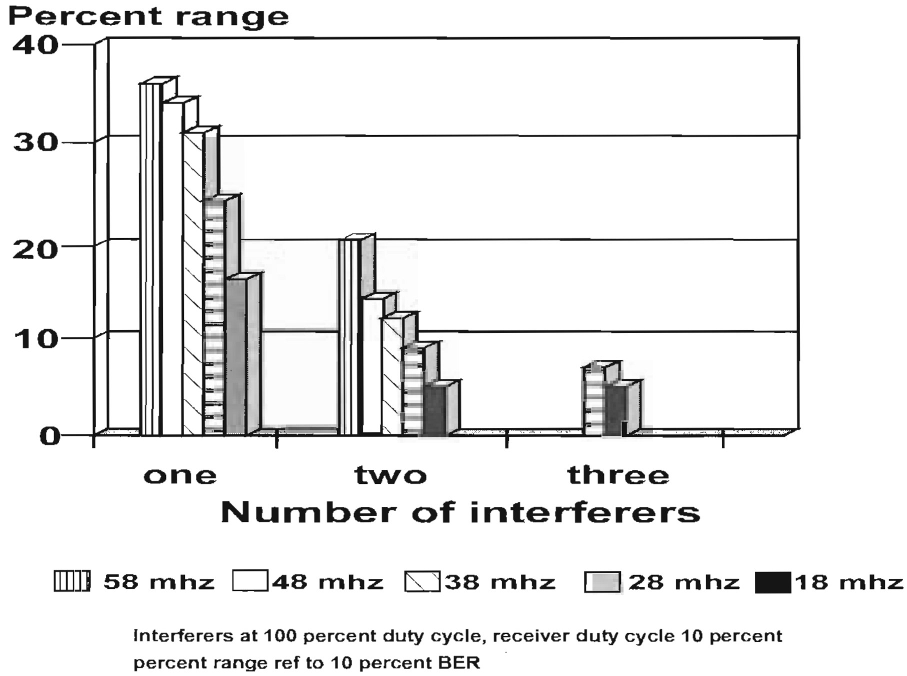

Figure 35. Range loss as a function of cosited radios and hopset bandwidth.

Equipment improvements

Even if all the measures described were applied at a particular CP by an intelligent Signal officer, the chances are still good that some degrading cosite interference will still exist. The current family of SINCGARS, MSRT, IHFR, SATCOM, EPLRS, communications equipment and common hardware and software automation equipment can be improved just so much by operational measures.

Figure 35 shows just how bad the situation can get using some current-model equipment at a transmitting power level above four watts and a transmit duty cycle of only 10 percent.

Obviously, we need technical improvements, and they are coming in several forms. Namely:

• **Second production SINCGARS.** Now in production, the second-source SINCGARS radio has incorporated significant modifications designed to radiated energy and cosite interference. Great improvements over the original SINCGARS radio cosite characteristics have been achieved (Figure 36) for lower data rates. This is a great start, since SINCGARS is our most common tactical radio, but we're not yet near the improvement level needed to properly serve our larger Force XXI CP configurations. Also, we already have tens of thousands of early-production radios that won't be replaced or upgraded.

• **SINCGARS systems improvement program.** SINCGARS SIP brings a large list of improvements to SINCGARS' performance that won't be covered here. The SIP program includes a set of modest ongoing improvements that will solve the cosite issue associated with one interferer at the lower data rates. SINCGARS SIP should begin fielding this year; however, plans for fielding SIP at critical CP locations for the specific purpose of reducing cosite interference are unclear at this time. Concerned Signal officers must be familiar with this effort and be ready to use the equipment at the proper places when available.

• **Frequency-hopping multiplexer.** To reduce the number of SINCGARS antennas required at a fixed or mobile CP, an FHMUX is being designed. This device multiplexes up to four SINCGARS radios onto one broadband antenna, usually mounted on an elevated antenna mast. Each radio is provided with a separate filter path that collectively covers the entire frequency range. At any instant, each radio is connected to a separate interference-reducing filter path. Collisions are handled by a priority switching scheme that directs the lower-priority radio signal into a dummy load until the frequencies diverge, thus reducing cosite interference.

While the FHMUX causes some signal loss, its filters produce very high channel-to-channel isolation (up to 50 decibels), so cosite performance improves. Also, using the elevated mast helps isolate the multiplexed radios from other CP radios. The FHMUX generates no out-of-band interference.

• **Active and passive filters and interference cancellers.** Several projects are now ongoing to design either filters or cancellation devices to improve the cosite characteristics of individual types of communications and automation equipment. Although some of these devices show real potential, they probably won't be ready in the near future so they won't be discussed here.

The eventual use of SINCGARS SIP and FHMUX, along

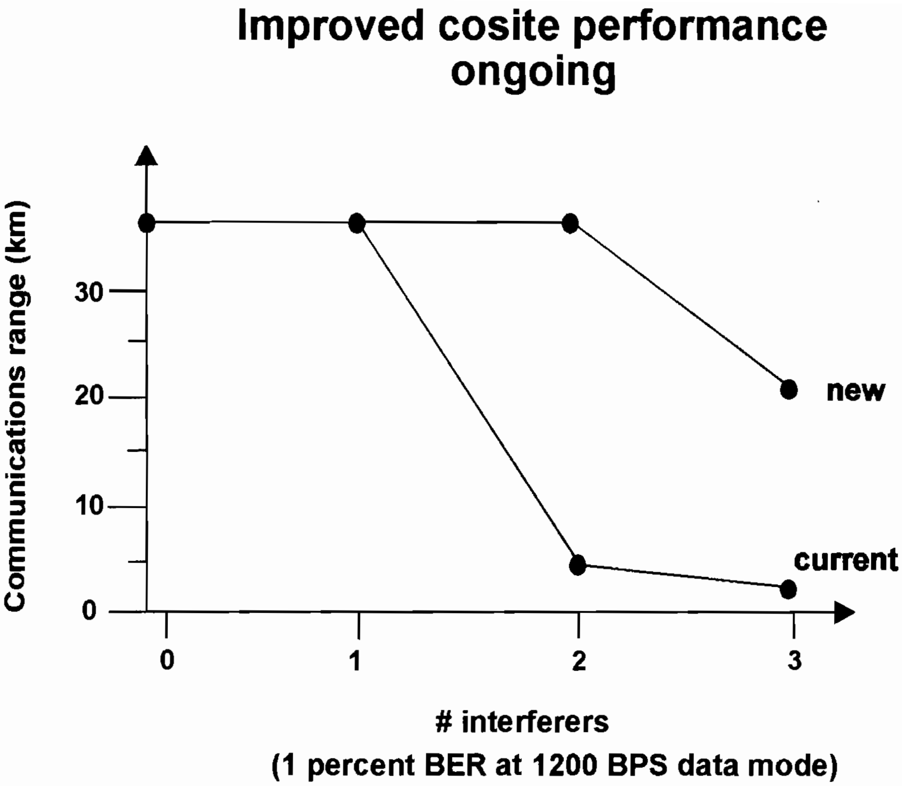

Figure 36. Improved cosite performance with more modern radios. The problem still exists, but more interferers can be tolerated.

Acronym Quick-scan

CONUS — continental United States
CP — command post
EPLRS — enhanced position-location reporting system
FHMUX — frequency-hopping multiplexer
HF — high frequency
IHFR — interim high-frequency radio
Mhz — megahertz
MSE — mobile-subscriber equipment
MSRT — mobile-subscriber radio terminal
RAU — radio-access unit
RF — radio frequency
SATCOM — satellite communications
SINCGARS — single-channel ground and airborne radio system
SIP — systems improvement program
S/N — signal to noise
UHF — ultra-high frequency
VHF — very-high frequency

with other devices and signal-processing techniques, will improve the cosite situation when available. Obviously, this improved equipment isn't going to appear overnight, nor will it solve 100 percent of the problem, particularly at the larger CPs. This indicates the mitigation techniques discussed earlier in this article will always be valid and required. The existence of so many generations of equipment will also be a burden for Signal leaders who must be aware of each piece of equipment's particular cosite characteristics and try to keep the right type at each location for the best performance.

These and other efforts, along with strong Signal leadership, must be developed and used to solve — or at least control — the cosite-interference problem. Or else Force XXI may never be able to leave the motor pool.

Retired LTC Fiedler is employed as an engineer and special assistant to the project manager, operational tactical data systems, Fort Monmouth, N.J. He has served in Army, Army Reserve and Army National Guard Signal, infantry and armor units and as a Department of the Army civilian engineer. He holds degrees in both physics and engineering and an advanced degree in industrial management. He is the author of many articles in the fields of combat communications and electronic warfare.