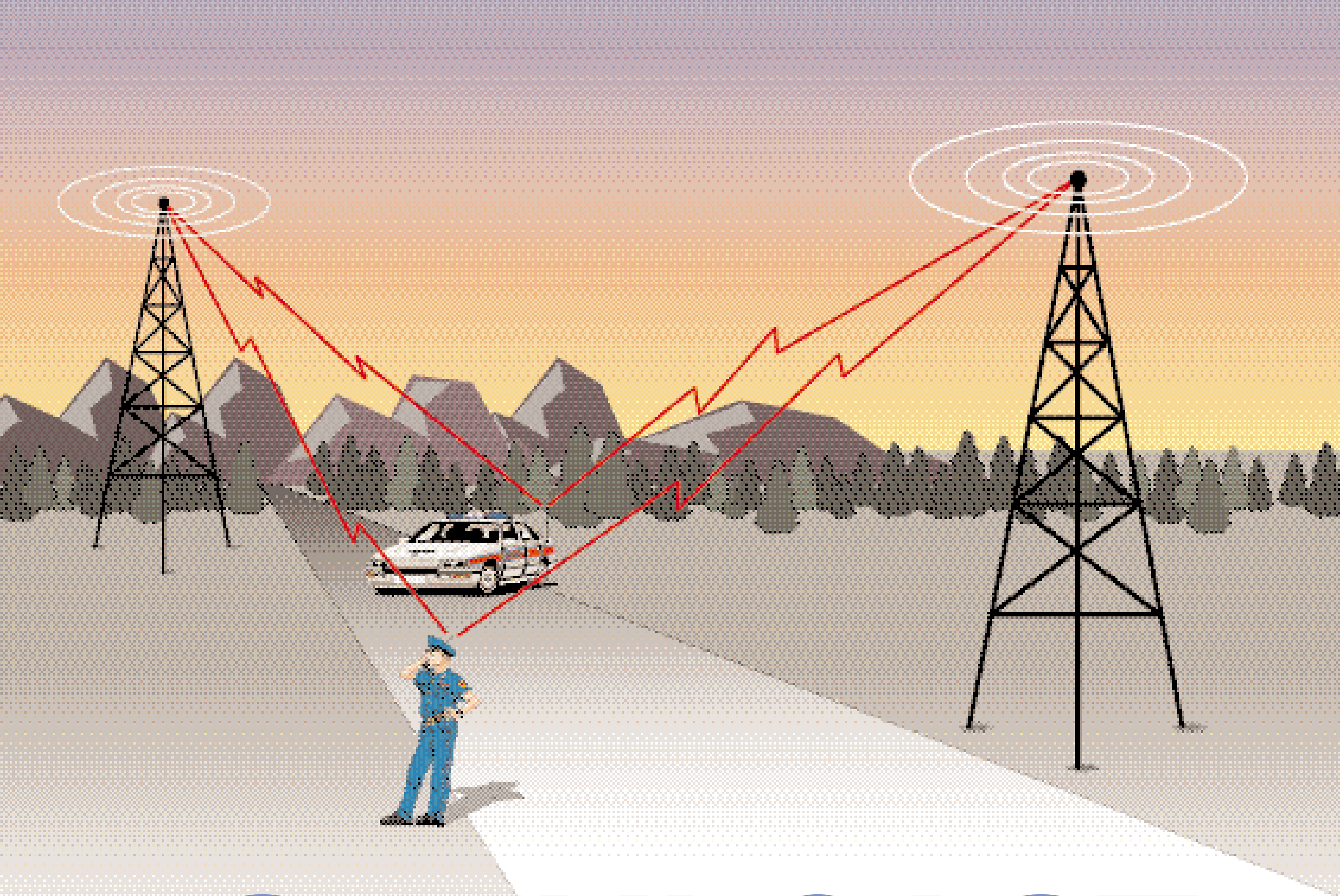

SIMULCAST

A Public Safety Communications Solution

By Ed O'Connor

The City of Lincoln and Lancaster County (Nebr.) needed a trunked radio system that would cover the entire city/county area — ease of use was critical to system success, and only a limited number of radio frequencies were available. To solve the problem, they purchased a two-site, 20-channel simulcast radio system that handles both voice traffic and 9600-baud data traffic from Com-Net Ericsson. Simulcast uses radio spectrum efficiently and covers large geographic areas by networking radio sites, making a multiple-site radio system as easy to use as a single-site system. Those benefits help to explain why simulcasting is used primarily in public safety applications. This article explores the basics of land mobile simulcast and provides a summary of manufacturers that sell conventional/trunked voice and data simulcast radio systems.

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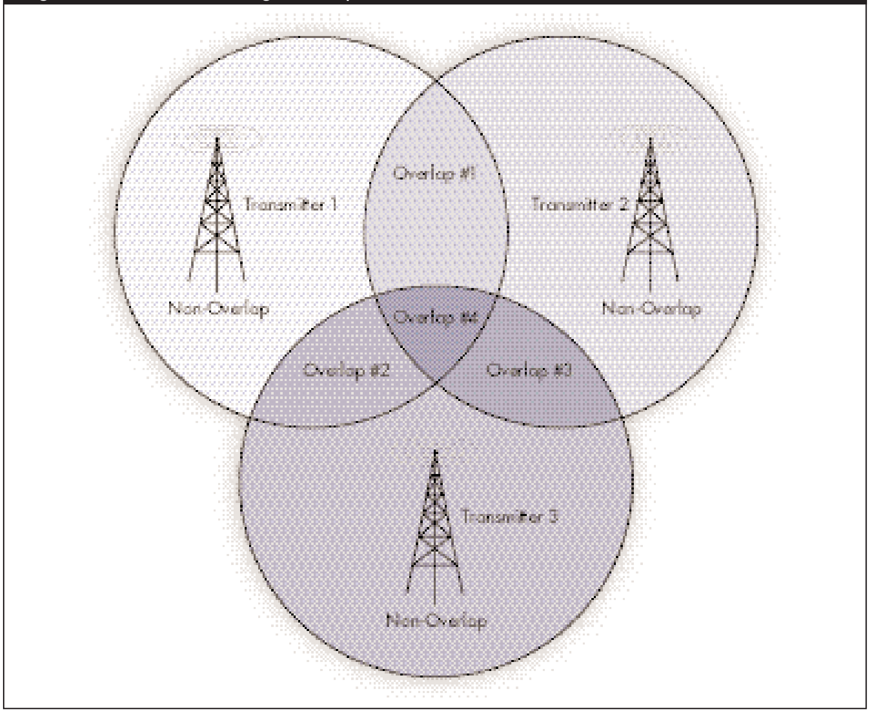
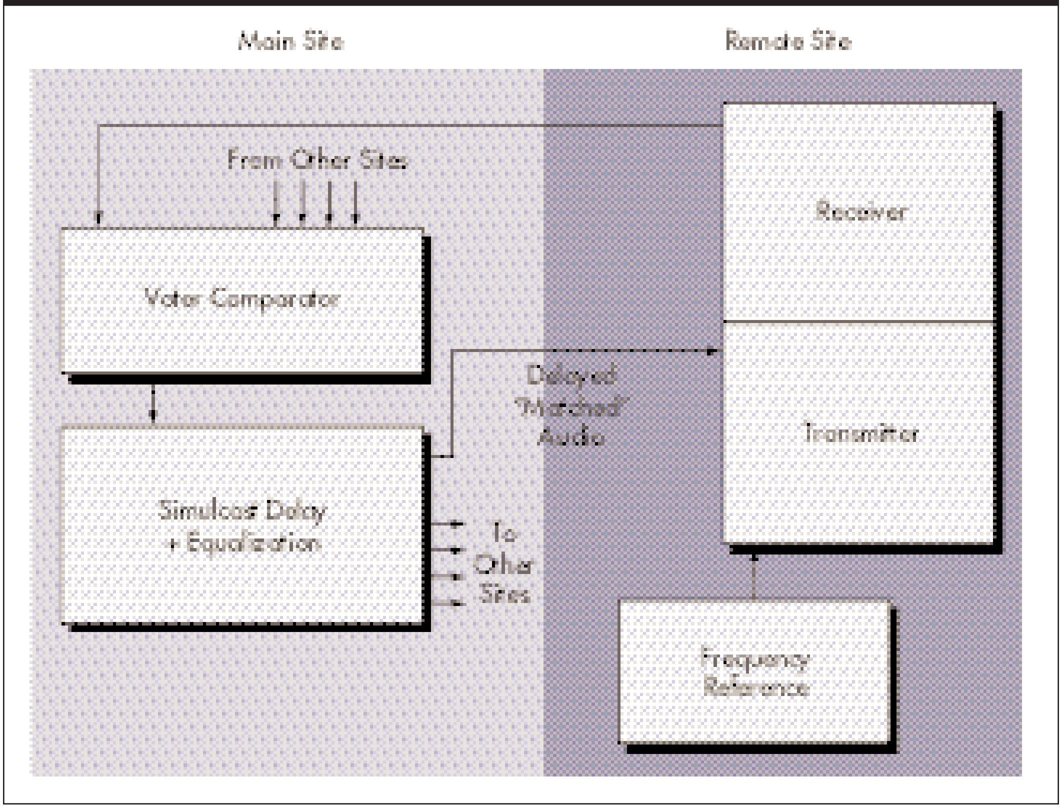
Figure 1: Simulcast coverage-overlap zones



The Basics

Simulcast is the abbreviation for simultaneous broadcast. It is the concurrent outbound transmission of the same modulation at the same carrier frequency from multiple locations. This technology has been around since the early 1960s, but has grown in popularity during the last decade. Signals in a simulcast system can be separated into two main types: areas where a mobile or portable radio receives a signal from only one transmitter (where one signal “captures” the receiver), and areas of noncapture, or overlap, (where the signal strength from adjacent transmitters is approximately equal). See Figure I for a visual representation of the simulcast overlap concept. In general, areas where a mobile receiver either receives one signal or is captured by the strongest signal cause few implementation problems. Overlap areas are the primary concern, as interference occurs in these overlap zones. How effectively interference is controlled determines the

Figure 2: Conventional simulcast system



quality of communications in this area.

Throughout North America, about 100 land mobile radio simulcast systems are installed every year for the following reasons: to achieve seamless wide area coverage with existing channels; to achieve better in-building penetration; to effectively multiply the number of useable channels since the frequencies do not have to be divided up between the sites.

Pros and Cons

Simulcast got an early reputation as hard to maintain, largely due to the analog hardware that was used. Hardware has made giant improvements over the last twenty years. Today's modern digital hardware is relatively easy to align, and needs no periodic realignment. It remains repeatable without drift for years.

The primary advantage to installing a simulcast repeater system is that all users hear the message, since signals are transmitted from all sites at the same time. This makes simulcast very frequency-efficient as a wide area solution. Additionally, operational simplicity for dispatchers and field personnel is a primary benefit.

Negatives of simulcast systems include the slight degradation in audio quality within overlap areas when analog transmissions are used. Analog and digital simulcast transmissions can be blanked out in small areas by destructive interference, such as multipath. In addition, simulcast requires costly additional hardware over a single-site radio system.

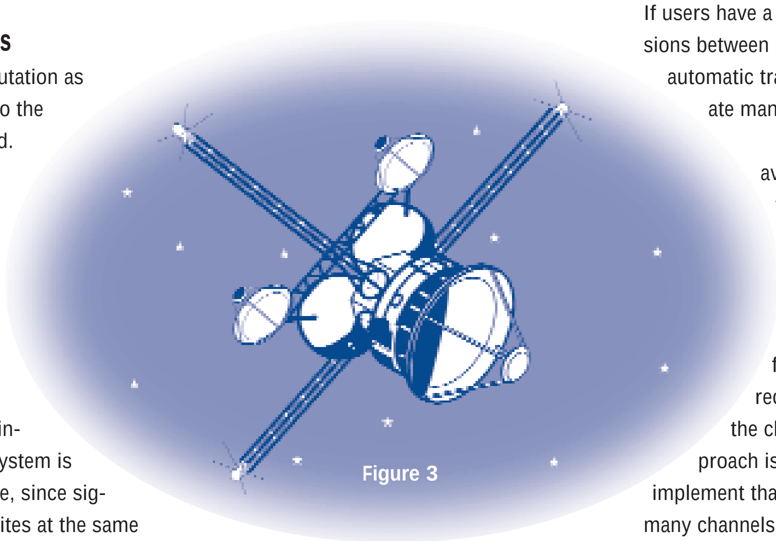


Figure 3

Explore All the Alternatives

While simulcasting is simple from an operational standpoint, it requires additional RF engineering, system design, hardware, and alignment. Before jumping on the simulcast bandwagon, fully explore all the alternatives.

Coverage issues may be solved simply by using a higher tower or a lower carrier frequency. In a simple conventional system with distinct coverage areas, manual transmitter steering may fulfill all system needs. Close attention is required on the part of the dispatcher; however, this is by far the easiest system to implement.

If transmissions are primarily dispatch-to-field, or field-to-dispatch, then automatic transmitter steering may be a viable option. In transmitter steering, the transmitter closest to the site with the best reception is automatically selected for the next transmission. This requires a voter comparator to select the best audio, as well as a transmitter steering controller to key the transmitter at the voted site. If users have a lot of field-to-field transmissions between nonoverlapping zones, automatic transmitter steering will generate many user complaints.

If enough frequencies are available, then multisite or multicast is viable. In multisite technology, different transmit and receive frequency pairs are used at each site. In multicast, different transmit frequencies are used, but the receive frequency is the same for the channel at all sites. This approach is less expensive and easier to implement than full simulcast, but requires many channels. Field units have to change

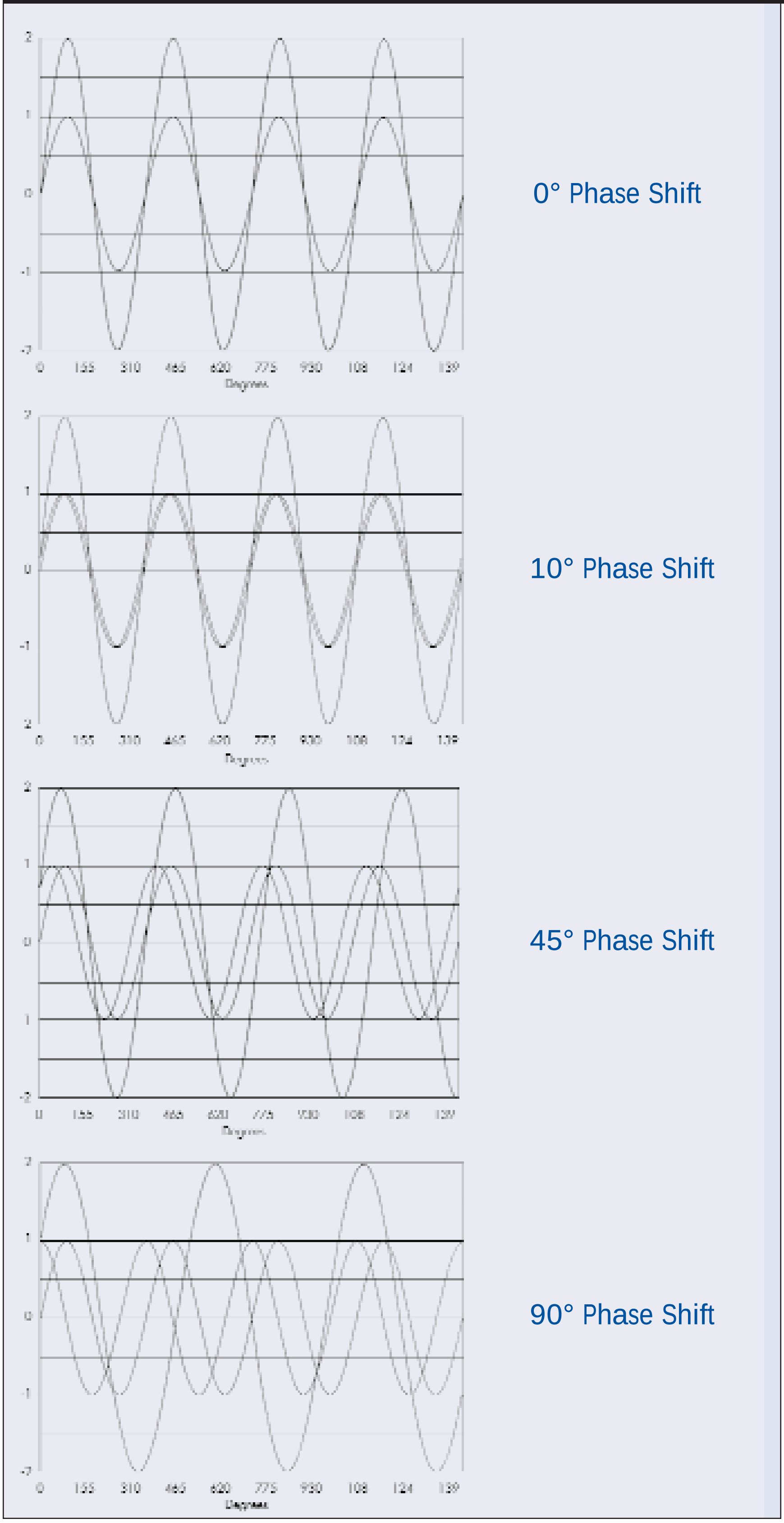


Figure 4: Simulcast phase distortion

channels as they travel from one area to another.

After all alternatives have been evaluated and determined to not be viable solutions to a communications problem, then simulcast may be the answer.

Technology Overview

The three keys to successful simulcast communications are accurate frequency control, precise audio matching, and exact modulation adjustment. A typical system block diagram is shown in Figure 2. Close attention to the factors listed above allows the "interference" from adjacent sites to be transformed into communications.

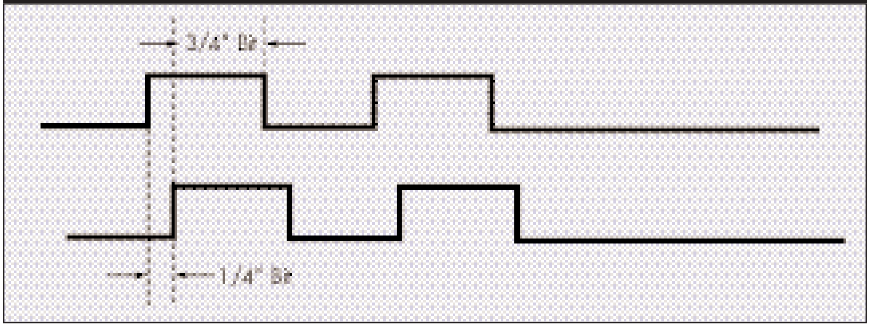
In the early days of simulcasting, frequency control was accomplished by using matched oscillators cut from the same crystal in a very stable temperature oven. This helped ensure that the frequency at all sites was very close, and would age in the same direction at approximately the same rate. However, this method required calibration at each transmit site every six to l2 months, and was most effective for low- and high-band systems. The recalibration interval for UHF and 800 MHz systems was so short as to be impractical. The next generation of frequency control used either an off-air standard, station WWVB in Ft. Collins, Colo., or rubidium oscillators. Rubidium oscillators are very accurate, free-running, atomic-frequency sources whose frequency drifts less than one hertz per year.

Currently, many generation systems use oscillators referenced to the U.S. Department of Defense global positioning system (GPS) (Figure 3). These signals come from a 24-satellite constellation, of which eight or more are typically visible to receivers anywhere in the world. Frequency accuracy is better than 0.0l hertz at the carrier frequency, as long as the unit is locked to the GPS transmission. This accuracy is overkill, but comes "free" from GPS.

Precise audio matching means two things: first, delaying audio or data so it arrives at the center of the overlap zone(s) at the same time; second, equalizing voice frequencies for variations between different transmission paths and base stations.

"Audio" is used as a generic term to describe analog audio, digital audio, or

Figure 5: Minimum recommended alignment of digital signals in overlap



data. The same laws of physics apply, although tolerances vary, depending on the baud rate used. Bulk delay can be achieved on individual voice circuits or at the T1/E1 level. Individual voice circuits are typically delayed by passive delay lines or microprocessor-based audio delay circuits. Equalizers are required to compensate for different characteristics in transmission lines or base station response variations, and usually have amplitude and component time-delay adjustments every 200 hertz over the voice band.

State-of-the art base stations and T1/E1 multiplexers do not require equalization because they are DSP-based, and not analog devices. However, some amount of audio delay is still required. This can be handled in 1- or 5-microsecond steps on individual voice frequency (VF) channels, or in 1-bit steps at the T1/E1 level (0.647 microseconds). See Figure 4 for a graphical representation of audio phase differences. A rule of thumb is, throughout the entire overlap zone analog audio should be aligned within 50 to 60 microseconds. Outside that tolerance, audio degradation will be detected. Audio can still be acceptable to about 100 microseconds, as long as there are no high-frequency paging tones. At 3000 Hz, a ±10-degree window at the center of the overlap translates to a maximum time error of ±10 microseconds. The time delay of a signal increases 5.2 microseconds every mile it travels from the transmitter.

Digital systems attempt to match 3/4 or more of an individual bit (Figure 5). For a 3600-baud channel, that translates to a 100-microsecond error tolerance; for a 9600-baud channel, a 40-microsecond tolerance is attained. Vocoders in digital systems synthesize high-quality audio when bits are error-corrected and decoded; however, destructive interference may occur and obliterate all communications outside the primary coverage area. In a digital system with bad alignment, instead of hearing garbled or "fuzzy" audio, there may be no sound at all.

Most systems now rely on the GPS on time point to automatically determine and compensate for any change in path length. This is vital if a telephone company's T1 or E1 lines are used to link sites together. Rerouting a line does keep the circuit live, but, without GPS realignment, wreaks havoc on communications in the overlap. The downside of relying on an external source for timing is that the system is not self-contained, which is an important consideration for public safety organizations.

Precise modulation adjustment by a monitor receiver is crucial to system performance. Service monitors are not accurate enough for this purpose. Modulation adjustment does not require extra hardware, just good test equipment and some time.

Although receiver voting is not an element in the outgoing — or simulcast — path, all simulcast systems have remote receivers at each transmit site and a voter comparator at the main site. This allows the best transmission from mobiles and portables to be selected, then repeated, using the simulcast system for widest coverage possible.

Table 1: Suppliers of simulcast systems

	Base Stations		Sync Source	
	trunked	conventional	off-air	self-contained
Com-Net Ericsson	Y	Y	Y	-
E. F. Johnson	Y	-	Y	-
Motorola	Y	Y	Y	-
Tait	-	Y	Y	Y

System Providers

Simulcast system suppliers are listed below, in alphabetical order, along with a brief technical description of how each company accomplishes audio and frequency control. Types of simulcast systems provided, synchronization sources, and geographies served are summarized in Table 1.

- Com-Net Ericsson Critical Radio Systems markets both trunked and conventional simulcast using Mastr III base stations. GPS/oven-controlled crystal oscillator (OCXO) frequency sources and multiplexers, which accomplish delay at the E1 or T1 level, are used. Delay is automatically adjusted for any change in path length.
- E.F. Johnson, a division of Transcrypt, supplies 800 MHz trunked MultiNet systems that use GPS/OCXO for frequency control. Delay is implemented in the individual remote site repeater controllers based on the GPS 1pps (pulse per second) on time point.
- Motorola offers trunked and conventional simulcast using its Quantar base stations, which typically use GPS/rubidium frequency sources and T1/E1 multiplexers. Delay is a function of the GPS on time point, and is accomplished with unique multiplexer cards.
- Tait Electronics has installed many conventional channel simulcast systems using its T800 series base station line. The Tait system uses a test receiver that offers easy, periodic system audio alignment. Audio cards flip subaudibles into the audio band so they can pass down a 300-3000 Hz line, and then be restored at remote sites. Frequency control is typically accomplished by using high-stability OCXO or stand-alone rubidium. The company is presently beta testing a new design that takes advantage of some advanced GPS features, such as continuous-tone coded squelch alignment, to lower initial system cost without increasing ongoing expense.

Other manufacturers of simulcast-ready base stations include Daniels Electronics, DX Radio, Kenwood Systems Group, and RF Technology.

Because of the high networked-software content of trunked radio systems, typically only OEMs handle trunked simulcast system design. However, throughout the world there are many regional systems integrators and radio dealers that design and install conventional simulcast systems using simulcast control equipment and base stations made by other manufacturers.

In summary, the use of simulcast will continue to grow. Efforts to understand and implement this technology represent an investment in the future of wide-area coverage radio communications systems.

Updates should be e-mailed to edit@radioresourcemag.com

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Ed O'Connor is president and founder of Simulcast Solutions, a supplier of specialized hardware products including frequency references, audio delay, and voter comparators for wide-area communications. Worldwide customers include major radio infrastructure OEMs, systems integrators, and end users.O'Connor can be contacted by phone at +I 7I6 223 4927 or visit the Web site at www.simulcastsolutions.com

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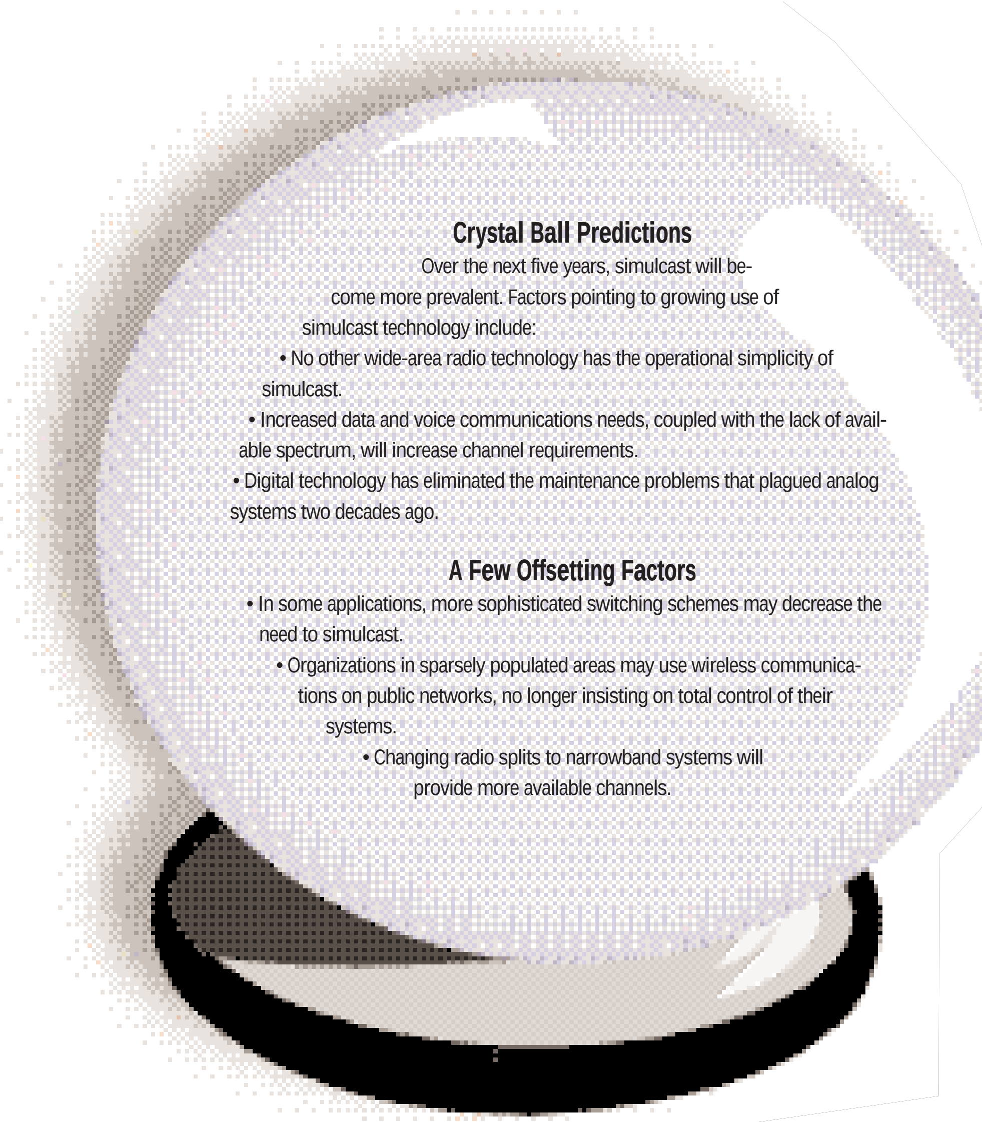

Crystal Ball Predictions

Over the next five years, simulcast will become more prevalent. Factors pointing to growing use of simulcast technology include:

- No other wide-area radio technology has the operational simplicity of simulcast.
- Increased data and voice communications needs, coupled with the lack of available spectrum, will increase channel requirements.
- Digital technology has eliminated the maintenance problems that plagued analog systems two decades ago.

A Few Offsetting Factors

- In some applications, more sophisticated switching schemes may decrease the need to simulcast.
- Organizations in sparsely populated areas may use wireless communications on public networks, no longer insisting on total control of their systems.
- Changing radio splits to narrowband systems will provide more available channels.