

Figure 1. A simplified schematic shows steps to take in placing multimeter probes onto the board to find the short. Although the printed circuit trace has extremely low resistance, only a few thousandths of an ohm per inch, a 0.5A current causes a

voltage drop of a few millivolts per inch. A multimeter set to its most sensitive scale shows this drop easily. Use the probes to find portions of the trace with a voltage drop and portions with no drop.

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TRACING A SHORT CIRCUIT

To use a multimeter to trace a short circuit on the positive power lead in a portable transceiver:

Solder a short piece of bus wire to almost any location along the shorted bus. The preferred position is near the center of its length.

Connect a power source that supplies about 0.5A current through the bus wire and, thus, through the short. The source could be a power supply with a feature that limits current or it could be a single C-cell battery in series with a 3 Ω resistor.

Some technicians still use the name, VTVM, to refer to a multimeter, although vacuum tubes have not been used by multimeter manufacturers for many years.

Today's multimeters have one thing in common with the old VTVM: extremely high impedance for measuring dc voltages. It is not uncommon to find multimeters with an input impedance on the order of 20 megohms. What does that mean to the technician? The multimeter will not load the circuit being measured, as a simple voltmeter would. For all practical purposes, 20M Ω is such a high input impedance that voltage readings taken with the multimeter are reliable.

But that does not mean you can measure *all* of the important voltages in a

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Today's multimeters have extremely high impedance for measuring dc voltages.

radio with a digital multimeter (or an analog multimeter). When they stopped building VTVMs, almost all of the manufacturers who began building solid-state multimeters left out an important item: a 1M Ω resistor at the end of the probe.

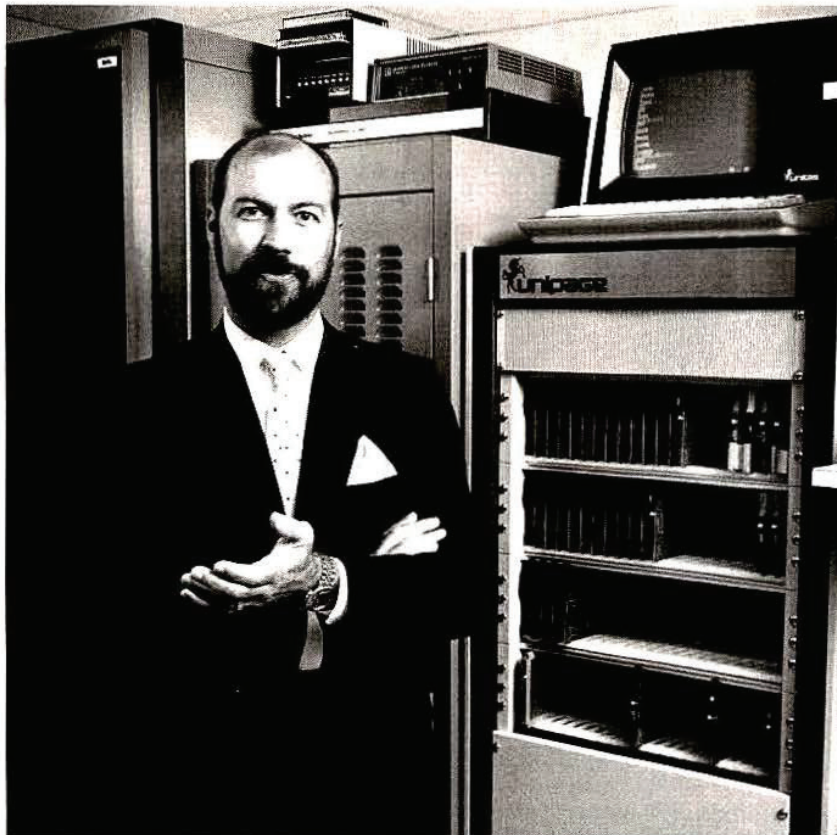
The resistor is important if the meter is used to measure voltage where RF is present. For example, if you use ordinary probes to measure voltage at the base of an oscillator, the capacitance of the leads usually kills the oscillation and the base voltage drops to the non-oscillating value.

Something similar happens when you place the probe on any of the RF or IF amplifier stages: The capacitance of the probe loads down the RF and usually upsets the dc value you set out to measure.

The cure is simple. Wrap one end of



unipage: Alert To The Situation.



Jeff Owens Vice-President Engineering, ProNet Inc., shown here with Unipage System 80.

With over 50,000 medical related subscribers depending on ProNet, Inc. to provide uninterrupted paging service Jeff Owens had to be certain he was making the right play. Jeff called on Unipage to carry the ball and on super bowl day 1988 the System 80 was installed in Dallas Texas . . . no fumbles-no missed pages. The final score was victory all around.

In the search for terminal alternatives Jeff was concerned about true expansion capability of the terminal he selected. Expressing his opinion on Unipage . . . "They are continually able to integrate new features with their technology, and, do it as part of the original design process. That is important when you are looking at a new product . . . any time you want to expand, you don't have to add a 'black box' on to make it work."

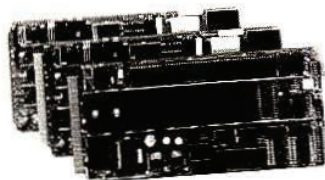
When asked how he viewed the Unipage terminal when comparing it to the others he evaluated, Jeff remarked . . . "In relationship to cost, there is no question that feature for feature and dollar for dollar Unipage stacks up number one."

On service, support, and engineering Jeff had to say . . . "it is really an asset to have a group of system engineers and technicians that will sit down with you . . . they are willing to work with you in solving your problems . . . Unipage is willing to do that."

The single reason ProNet decided on the Unipage terminal over all the others available . . . "ProNet provides high reliability communication services to the medical community. We went to the market place

initially seeking improvement for the processing of priority pages. The Unipage System 80 addressed our priority requirement and improved system thru-put. In addition, we got a redundant terminal system all for the same dollars others wanted for priority alone. The decision to go with Unipage just made good sense."

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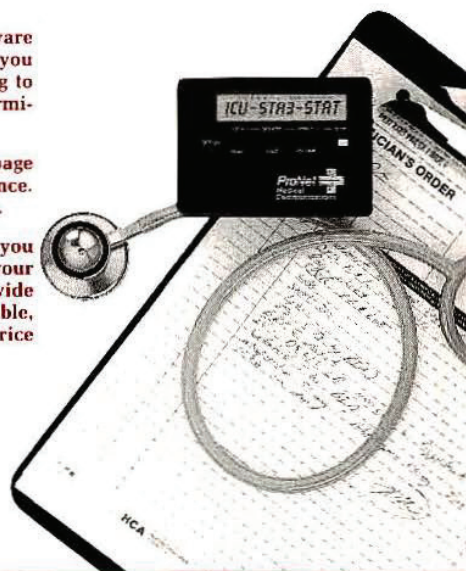
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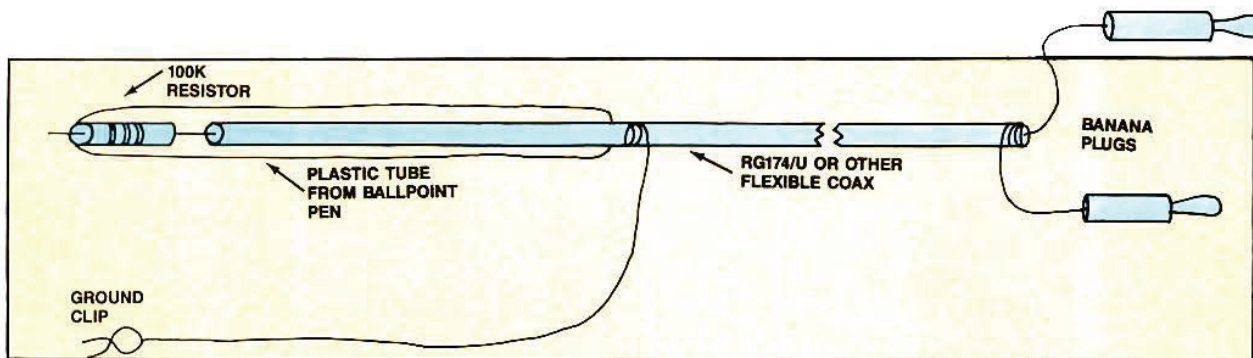
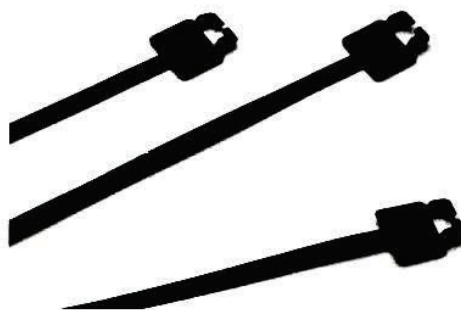
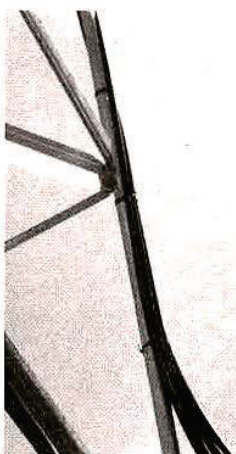


Figure 2. Make your own test leads for taking voltage measurements on RF circuits. The parts you will need are a piece of plastic tubing, some RG188/U and two plugs that fit your multimeter.



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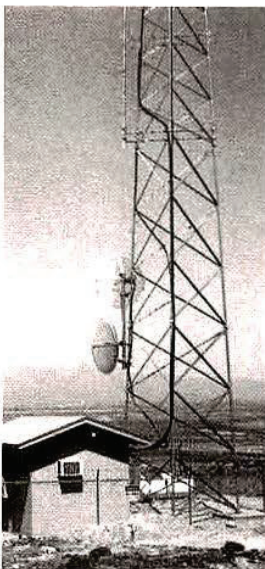
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a resistor around the test probe tip and use the other end to connect to the sensitive circuit location. A resistor as small as 100,000Ω will avoid the loading effect. One as large as 1MΩ would only give you a 5% error with the typical 20MΩ input impedance found in today's test instruments. The 100,000Ω resistor is a good choice; the error it introduces is only 1/2 of 1%, a negligible value for any service measurement.

Custom test lead

You can make your own test leads for making measurements on RF circuits. The parts you will need are a piece of plastic tubing, some RG188/U and two plugs that fit your multimeter (Figure 2 above).

The handcrafted test lead is even better than the ones formerly provided with VTVMs. The VTVM lead usually came with a rather large pin holder assembly at the end. The assembly probably added one or more picofarads of capacitance. The custom test lead avoids additional capacitance because the resistor lead serves as the probe tip, and it is clipped so it is only about 1/8-inch long. The loading capacitance is truly tiny—small enough to create little detuning on the most sensitive circuits.

The resistor lead wears down after repeated use. But resistors cost less than 1 cent, so the operating expense on the probe really is quite reasonable.

A future article will explain how to use the digital multimeter to test diodes and transistors, as well as a powerful troubleshooting technique that uses the diode test in conjunction with the meter's ohmmeter function.



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ACSSB advancements improve data transmission

Synchronous transmit-receive control eliminates received-signal offset and virtually eliminates phase and amplitude effects of multipath fading. The result: higher data speeds with less error-correction overhead.

By Douglas P. Collette

With the advent of the microprocessor, modern digital control systems are providing a level of performance and sophistication that was only a dream 10 or 20 years ago. Supervisory control and data acquisition (SCADA) systems control and monitor a vast array of functions at hundreds of locations, saving untold time, manpower and money.

One obstacle to SCADA system implementation is the requirement that a data communications net-

work transfer data between the central station and remote sites, primarily either by wireline or radio. Wireline historically has been the more popular of the two, but that is changing rapidly today. Since AT&T divested its operating companies, monthly tariffs on leased wirelines have increased from fourfold to tenfold in many areas, causing an unprecedented number of data communications users to abandon leased wirelines in favor of radio telemetry. The payback period for conversion from wireline to radio can be as short as one to two years.

For radio communications and telemetry systems, frequency modulation (FM) is by far the most popular

modulation technique, and for good reason. FM equipment is relatively inexpensive, provides excellent voice and data quality and is widely available from a multitude of manufacturers. But FM also has its drawbacks, mainly, the relatively large amount of RF bandwidth required for a given audio bandwidth and the adverse effects of multipath fading on digital data.

Today's FM radio equipment typically requires 16kHz of RF bandwidth for an audio bandwidth of 3kHz. If radio spectrum were unlimited, the fivefold increase in RF bandwidth would not be a problem. Unfortunately, radio spectrum is a limited resource, and we nearly have used it up in this country.

Radio channels in most major cities may have 100 or more users per channel, and this number grows daily. The private radio community has used VHF lowband and highband widely for many years because of the propagation quality. As VHF frequencies became saturated, users began moving into the UHF band. Eventually the FCC began allocating UHF TV channels for land mobile use. The latest allocation is in the 800MHz to 900MHz band. Unfortunately, as a general rule of thumb, as the frequency goes up, the price goes up, and the range goes down. At frequencies in the 800MHz band, foliage and terrain can limit the operating range severely.

In a mobile environment, multipath (Rayleigh) fading can affect data adversely, even in strong signal areas. Every time the vehicle drives

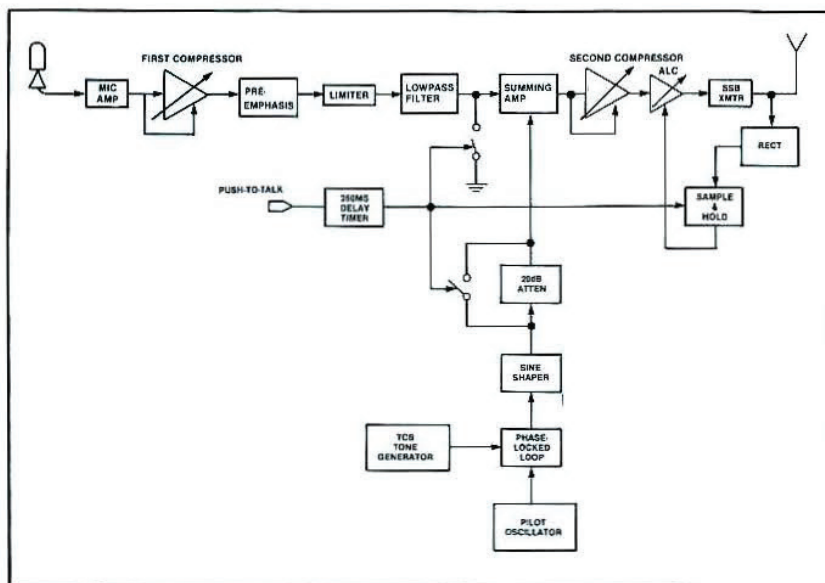


Figure 1. ACSSB transmitter block diagram. Current radio models use pilot tone at 3,100Hz and an audio passband from 300Hz to 2,500Hz.



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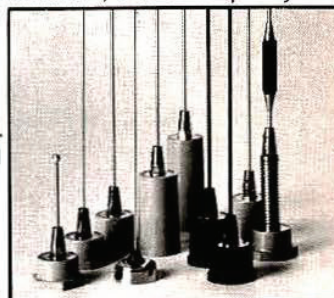
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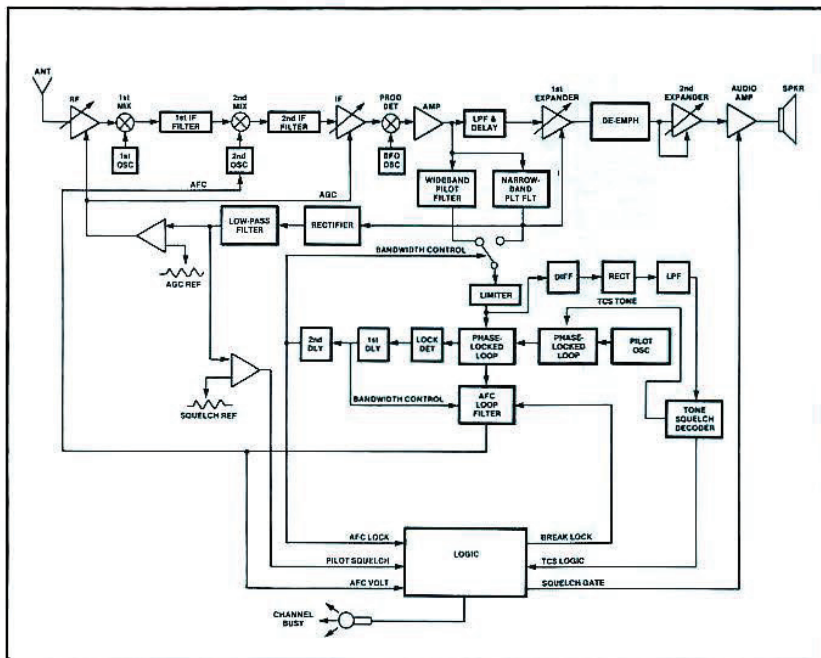


Figure 2. ACSSB receiver block diagram. Current radios phase-lock the receiver tuning to the transmitted pilot tone, using a locally derived pilot reference. A tuning error exists, but usually is 0.1Hz or less.

through the fade, the RF carrier phase changes, causing audible clicks and pops in the received signal. Although these clicks are a minor annoyance on voice signals, they can cause bit errors that result in garbled data. This problem is worse at higher RF frequencies because fades occur more often.

Anyone who has operated a mobile data terminal through an 800MHz radio at expressway speeds undoubtedly has encountered these fading-induced bit errors. To correct for these errors, mobile data terminal manufacturers usually incorporate either feed-forward error correction or error detection and retransmission. Both of these techniques can reduce the effective data throughput of the system significantly, resulting in slower system operation and increased use of valuable airtime.

Fortunately, modern technology has provided an answer to the problems encountered with FM. Ten

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In the olden days of **two way radio**, there were names like DUMONT, GALVIN, LINK and many others. They made fine radios. Somewhere along the line, the 90-day warranty was invented and became a permanent fixture in two-way radio sales brochures.

Unbelievably, the old 90-day warranty is still in existence today. It's really amusing to observe that some big companies still offer such an out-of-date warranty plan.

For those of you who prefer a more modern approach, we'd like to tell you about a warranty policy that FUJITSU TEN invented. We're not one of the "OLD TIMERS," so we think differently.

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years ago the FCC, realizing that radio use was growing at a rapid rate, commissioned a study to determine whether there were more efficient alternatives to FM.

The FCC's UHF task force, under the direction of Dr. Raymond Wilmotte, contracted with Dr. Bruce Lusignan of Stanford University to develop a new form of modulation that combines the performance advantages of FM but occupies a fraction of the RF bandwidth. After several years of research and development, amplitude companded single-sideband (ACSSB) resulted. Some manufacturers refer to the mode as ACSB. It is a form of single-sideband (SSB) that combines most of the advantages of FM, plus a few of its own, and yet occupies only one-fifth of the RF bandwidth of current FM systems.

Single-sideband is a well-proven modulation technique that has been used widely by the military and ra-

dio amateurs. Its use has remained popular because of some important advantages, although it has some significant drawbacks as well. Table 1 on page 34 lists the advantages and drawbacks of SSB and how ACSSB overcomes the drawbacks.

ACSSB eliminates the disadvantages through the addition of amplitude companders and a pilot tone. The amplitude companders consist of compressors in the transmitter and expanders in the receiver to improve the signal-to-noise performance and to provide a capture effect comparable to FM. The pilot tone is a reference tone that is added to the transmitted signal to provide a reference for the receiver's phase-locked loop tuning. The tone also can be frequency-modulated to provide subaudible tone information.

In 1985, after four years of actual on-the-air tests by thousands of voice and data users, the FCC authorized narrowband 5kHz channels

in the 150MHz to 174MHz band, creating hundreds of new channel assignments. Although the new 5kHz narrowband channel assignments are available to any form of modulation that can meet the 3.6kHz maximum occupied bandwidth limitation, ACSSB is the only commercially available narrowband technology proven to be practical.

Numerous technical articles deal with present ACSSB theory of operation, so the theory will not be covered in any depth in this article. Figures 1 on page 26 and 2 on page 28 show diagrams of an ACSSB transmitter and receiver. In ACSSB radios currently manufactured by several vendors, the pilot tone is at 3,100Hz, and the audio passband is from 300Hz to approximately 2,500Hz. The receiver is phase-locked to the transmitted pilot tone, using a locally derived pilot reference.

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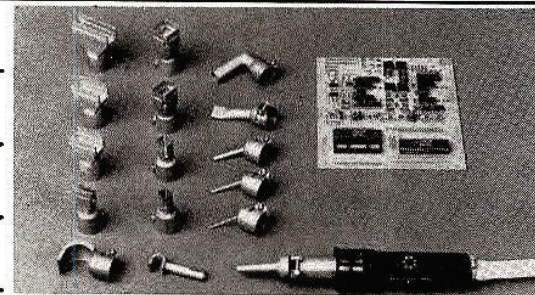
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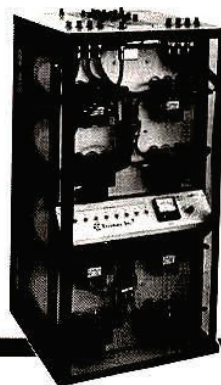
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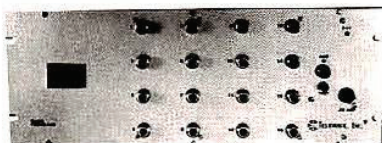
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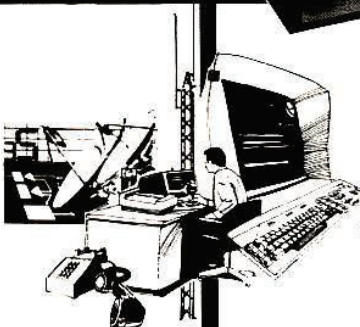
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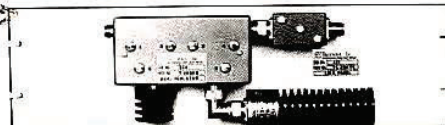
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and the receiver reference pilot tone are derived from two independent oscillators, there is a slight receiver tuning error and, hence, a frequency offset in the received signal. The tuning error is equal to the absolute frequency difference between the two pilot tone oscillators. Fortunately this error is extremely small, on the order of 0.1Hz, because of pilot tones being derived from high-frequency crystal oscillators.

For most types of point-to-point data transmission, including DTMF, AFSK, APSK, QPSK and QAM, the 0.1Hz frequency offset is insignificant, and excellent bit error rate performance can be achieved. Figure 3 on page 36 is a curve of bit error rate vs. carrier-to-noise ratio for 300, 600, 1,200 and 4,800bps data.¹ These data were taken using ACSSB voice radios operated through the ANIK B satellite.

ACSSB data radios have been built and optimized for data by eliminating pre-emphasis and de-

emphasis networks and by modifying audio lowpass filters to minimize group delay. These data radios achieve approximately a 5dB improvement in carrier-to-noise ratio for the same bit error rate.

Many ACSSB data systems are in daily use in this country. The first one was installed in Tampa, FL, to control bridge and expressway traffic signs. Several SCADA systems have been implemented for oil and natural gas pipeline control, and one radio network is part of a complex system to monitor highway icing conditions and relay data to the local highway patrol office.

The largest system to date belongs to a major utility for use in its nuclear power plants. The system, when fully implemented, will use more than 300 ACSSB data radios to report radiation levels, wind direction and velocity, and temperature at hundreds of locations around the utility's nuclear plants. In addition, the system will energize

warning sirens in the event of an incident at one of the plants.

Advancements in ACSSB technology soon will result in a second generation of narrowband product with important advantages. This new generation of radio will be synchronous—that is, there will be no frequency offset in the received signal—and both the phase and amplitude effects of multipath fading can be eliminated in all but weak-signal conditions. What makes this possible is that the pilot tone can be used as an artificial carrier during the modulation-demodulation process. Figure 4 on page 40 is a block diagram of the audio processing using this new technique.

The transmit audio first is passed through a 3,100Hz notch filter that removes any audio components that may be present at the pilot frequency. A lowpass filter follows to remove any audio components that are above the pilot tone. The audio signal then is mixed with the

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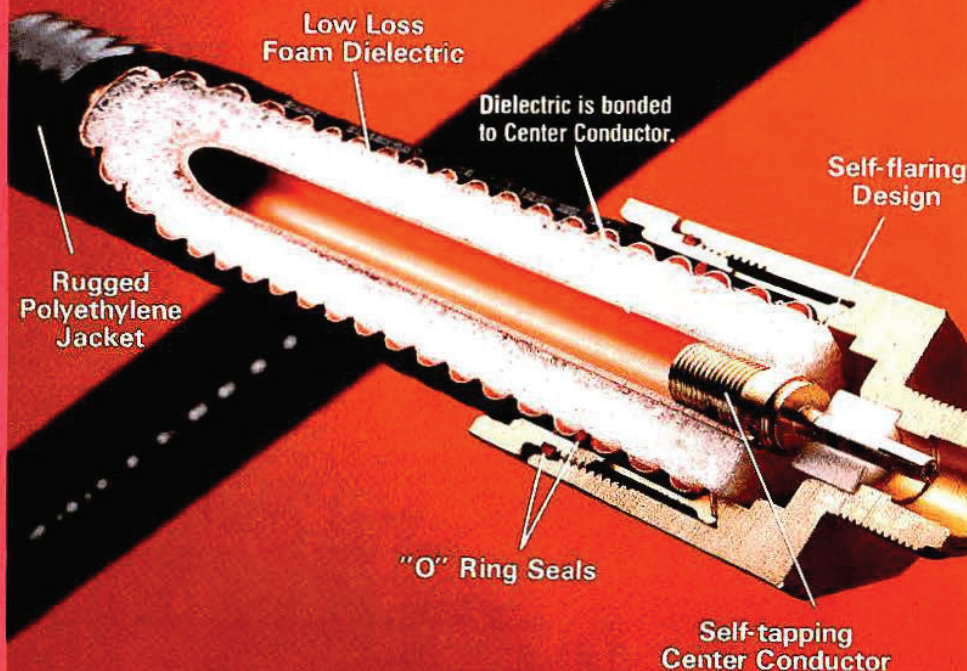
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TABLE 1—Comparison of single-sideband and ACSSB.

SINGLE-SIDEBAND

Advantages

- 1) Extremely spectrum-efficient—RF bandwidth is the same as the audio bandwidth.
- 2) Extremely power-efficient—Transmitter produces no power until it is modulated. Average power is only a fraction of peak power.
- 3) Excellent signal-to-noise—All the transmitter power concentrated in sideband where the information is contained. Receiver has much narrower bandwidth than FM.

Disadvantages

- 1) Receiver tuning critical—If tuning is incorrect, voice will be offset in frequency by same amount as tuning error. Can result in "Donald Duck" sound of SSB.
- 2) Subaudible signaling not possible—Radio sideband filter rolls off sharply below 300Hz to achieve adequate attenuation of the opposite sideband. Does not allow subaudible CTCSS operation.
- 3) Difficult to send data—Receiver tuning errors preclude any form of data transmission requiring receipt of accurate tone information such as DTMF, AFSK and APSK.
- 4) Lack of capture effort—Capture effect is the ability, when receiving two signals, to hear only the stronger signal, allowing more frequent reuse of existing channels. Amplitude modulated systems, because they do not use limiters, provide no capture effect.

ACSSB

Advantages

- 1) Very spectrum-efficient—RF bandwidth is only a few hundred hertz greater than the audio bandwidth.
- 2) Very power-efficient—With no voice, only pilot is transmitted at one-tenth of peak power. Average power is only a fraction of peak power.
- 3) Superior signal-to-noise—Amplitude companders enhance the already excellent signal-to-noise. Receiver has much narrower bandwidth than FM.

Solutions

- 1) Receiver automatically is tuned by phase-locked-loop tuning circuit that locks to the pilot tone.
- 2) Subaudible tones are generated by a low deviation FM modulation of the pilot tone.
- 3) Automatic tuning circuits limit frequency offsets to 0.1Hz. Usable with most forms of data.
- 4) The receiver expander circuits provide a capture effect similar to FM.

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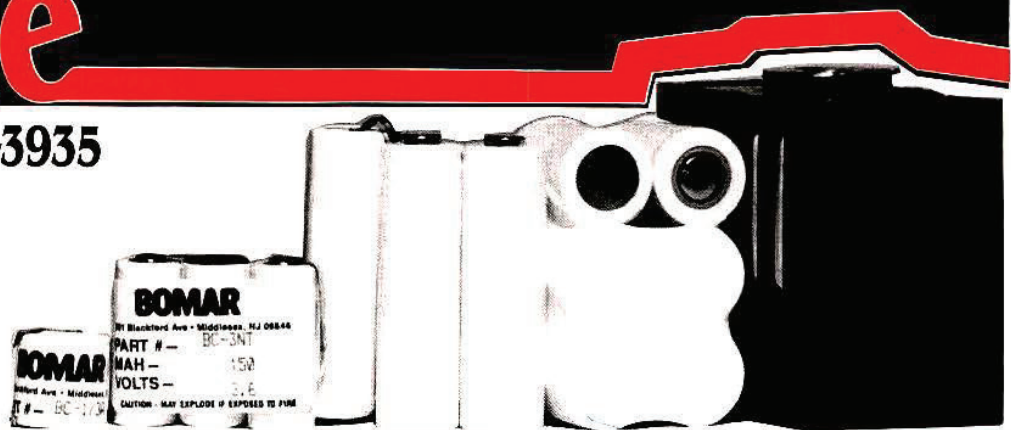
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☒ **Status reports**

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you to interrogate status and receive a spoken report.

☒ **Pager signalling**

You can even send voice or alphanumeric

messages to specific people by using signalling options such as Two-Tone, GOLAY or POCSAG.

☒ **Remote control**

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3,100Hz pilot tone to produce two frequency spectrums: the sum (3,100Hz + audio) and the difference (3,100Hz - audio). The balanced mixer output is then lowpass-filtered to pass only the difference spectrum, resulting in an audio signal that is inverted around the 3,100Hz pilot.

The mixing is an important step because this is where the transmitted pilot tone enters the modulation process and becomes an artificial carrier. The inverted audio then is routed to a summing amplifier

AUDIO/PILOT TONE

Mixing audio with recovered pilot tone in the receiver:

- (1) Removes the audio frequency inversion.
- (2) Eliminates any frequency offset.
- (3) Removes the phase effects of multipath fading.

where the 3,100Hz pilot tone is added. Note that this is the same 3,100Hz tone previously mixed with the audio. The composite signal, inverted audio plus pilot, modulates the single-sideband transmitter.

The composite audio signal from the receiver first is split into an audio channel and a pilot channel. The 3,100Hz notch filter removes pilot tone from the audio and the narrow pilot filter is a bandpass filter that passes only pilot tone. The audio then goes through a CCD delay line to delay the audio signal slightly to compensate for the much longer time delay of the pilot signal through the narrow pilot filter.

Delayed audio signal is then lowpass-filtered to remove any noise or distortion products that may be above the pilot frequency. The signal then is mixed with received 3,100Hz pilot tone and lowpass-filtered to pass only the difference spectrum. Just as mixing audio with pilot tone in the transmitter used the pilot as a carrier for the modulation process, mixing audio with recovered pilot tone in the receiver uses the pilot as a carrier for the demodulation process. The benefits of doing this are the following:

(1) *Removes the audio frequency inversion*—Because the audio already was inverted, inverting it again returns the audio to normal.

(2) *Eliminates any frequency offset*—Because the recovered audio frequency is the difference between the pilot and audio frequency components of the received signal, the recovered audio frequency is independent of receiver tuning. Receiver tuning need be only sufficiently accurate to place received pilot tone within the pilot filter passband.

(3) *Removes the phase effects of multipath fading*—The phase variations of multipath fading result in a frequency modulation of the received composite signal. Because all components of the received signal shift in frequency together, the difference frequency remains constant, thereby removing the phase effects of multipath.

After the mixer and lowpass filter, the audio level is controlled by a feed-forward gain control stage.

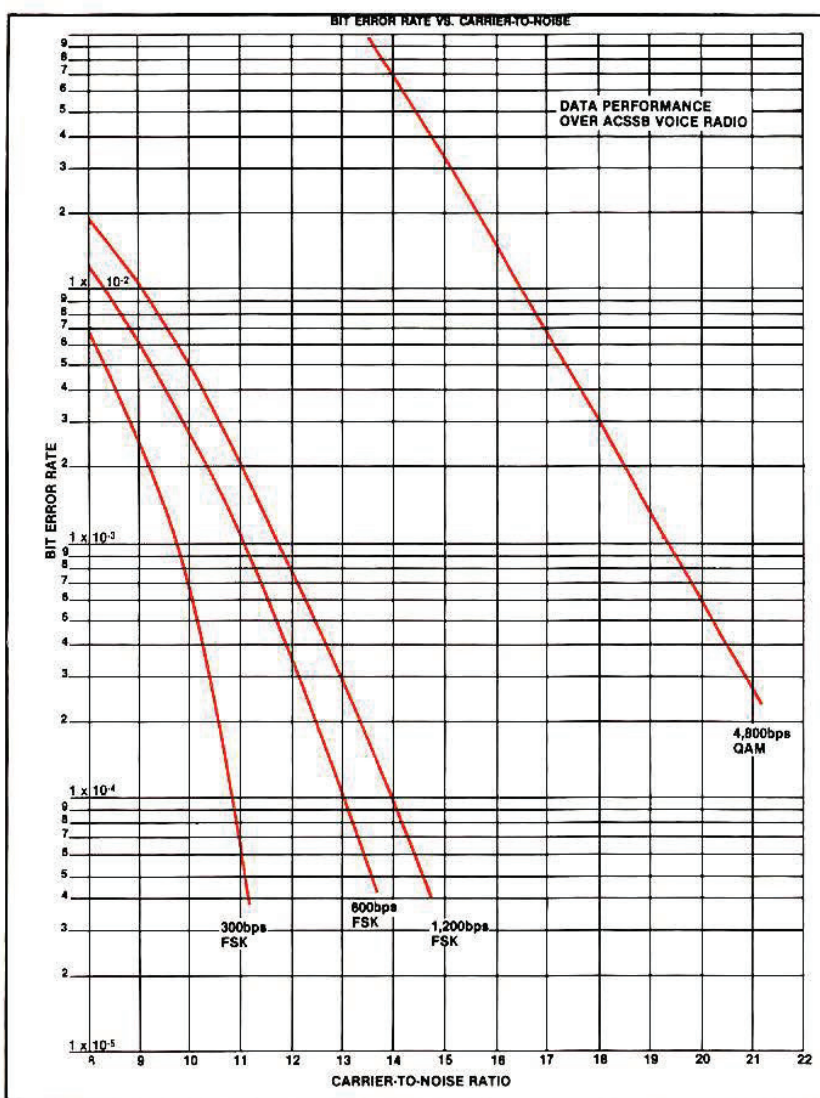


Figure 3. Data plotted represent bit error rate vs. carrier-to-noise ratio at several data rates. The data were taken using ACSSB voice radios operated through the ANIK B satellite. ACSSB radios designed for data-only transmission have an improved carrier-to-noise ratio that is 5dB greater for the same bit error rate.

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This stage is a variable gain amplifier whose gain varies inversely with the pilot tone level. This stage removes the amplitude variations due to multipath fading. For example, with a 10dB fade, the amplitude of the audio and pilot components decreases 10dB. As the pilot level decreases 10dB, the amplifier gain increases by 10dB, thereby restoring the audio level to its original prefade level. A muting circuit inhibits the output until a signal is received.

With the technique described above, the system's low-frequency audio cutoff is determined by the audio lowpass filters' corner frequency, and the high-frequency cutoff is determined by the radio sideband filter's low-frequency response. Even though the system's normal audio bandwidth response would range from 300Hz to 2,700Hz, the response can be tailored somewhat, if required, by changing the filter's characteristics.

ACSSB has several advantages

besides those already discussed. Unlike FM, ACSSB provides a linear channel and thus affords the possibility of transmitting combined amplitude and phase-encoded digital information with the associated improvements in bandwidth efficiency and error performance.

By employing high-level modem techniques such as quadrature amplitude modulation (QAM), a technique used in commonly available 9,600bps telephone modems, it should be possible to transmit data at rates approaching 20,000bps within 5kHz spaced channels. In fact, a QAM radio modem could be far simpler than a telephone modem because the radio's phase and amplitude distortion are known and fixed, and, thus, the radio path does not require adaptive equalization the way a telephone system does.

Coherent phase-shift keying (CPSK), although recognized as having the lowest bit error rate in the presence of white noise of all

known forms of data modulation, cannot be used effectively in some mobile data applications because of the irreducible error rate caused by random FM induced by multipath fading.

The irreducible error rate, because it is caused by the phase variations of multipath fading, does not get better as the signal becomes stronger. In fact, at frequencies in the 900MHz range, the irreducible error rate can be as high as 1×10^{-1} at a vehicle speed of 70mph. Clearly, if the best bit error rate that can be achieved is one wrong bit out of every 10, then enormous feed-forward error correction overhead will be required for successful message retrieval.

With some modifications to ACSSB circuitry, the pilot tone can be used as the reference for coherent detection. This technique has been successfully used by Bateman² and others at the University of Bath in England. These tests proved that a

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RM-35A	25	35	5 1/4 x 19 x 12 1/2	38
RM-50A	37	50	5 1/4 x 19 x 12 1/2	50
• Separate Volt and Amp Meters				
RM-35 M	25	35	5 1/4 x 19 x 12 1/2	38
RM-50 M	37	50	5 1/4 x 19 x 12 1/2	50
RS-4A	3	4	3 3/4 x 6 1/2 x 9	5
RS-5A	4	5	3 1/2 x 6 1/8 x 7 1/4	7
RS-7A	5	7	3 3/4 x 6 1/2 x 9	9
RS-10A	7.5	10	4 x 7 1/2 x 10 3/4	11
RS-12A	9	12	4 1/2 x 8 x 9	13
RS-20A	16	20	5 x 9 x 10 1/2	18
RS-35A	25	35	5 x 11 x 11	27
RS-50A	37	50	6 x 13 3/4 x 11	46

• Switchable volt and Amp meter				
RS-12M	9	12	4 1/2 x 8 x 9	13
• Separate volt Amp meters				
RS-20M	16	20	5 x 9 x 10 1/2	18
RS-35M	25	35	5 x 11 x 11	27
RS-50M	37	50	6 x 13 3/4 x 11	46

• Separate Volt and Amp Meters • Output Voltage adjustable from 2-15 volts				
• Current limit adjustable from 1.5 amps to Full Load				
@ 13.8VDC @ 10VDC @ 5VDC @ 13.8V				
VS-20M	16	9	4	20
VS-35M	25	15	7	35
VS-50M	37	22	10	50
• Variable rack mount power supplies				
VRM-35M	25	15	7	35
VRM-50M	37	22	10	50

5 x 9 x 10 1/2	20
5 x 11 x 11	29
6 x 13 3/4 x 11	46

5 1/4 x 19 x 12 1/2	38
5 1/4 x 19 x 12 1/2	50

*ICS—Intermittent Communication Service (50% Duty Cycle 5 min. on 5 min. off)

*ICS—Intermittent Communication Service (50% Duty Cycle 5 min. on 5 min. off)

DC-DC CONVERTERS

MODEL 1212

MODEL 1212-18

MODEL 1212 & 1212-18 Switching Regulated Converter.

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Input—12V DC (Positive ground only). Functional from —11 V DC to—16 V DC. Output +13.8 V DC (Negative ground only).

	1212		1212-18
Output Voltage	13.8 V DC	±.2 V DC	13.8 V DC ±.2 V DC
Line/Load Regulation	200 mV		200 mV
Ripple/Noise	50 mV RMS		50 mV RMS
Current Continuous	6 Amp		14 Amp
Current (ICS)	9 Amp		18 Amp
Current Limit	12 Amp		19 Amp
Case	2 3/4" (H) x 6" (W) x 6" (D)		2 3/4" x 6" x 12"
Shipping Weight	2 lbs.		4 lbs.

MODEL 2412

MODEL 2412-16

MODEL 2412 & 2412-16 Switching Regulated Converter.

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Input +28 V DC (Negative ground only). Functional from + 22 V DC to +32 V DC. Output +13.8 V DC (Negative ground only).

	2412		2412-16
Output Voltage	13.8 V DC	±.2 V DC	13.8 V DC ±.2 V DC
Line/Load Regulation	200 mV		200 mV
Ripple/Noise	50 mV RMS		50 mV RMS
Current Continuous	9 Amp		16 Amp
Current Limit	12 Amp		20 Amp
Case	2 3/4" (H) x 6" (W) x 6" (D)		2 3/4" x 6" x 12"
Shipping Weight	2 lbs.		4 lbs.

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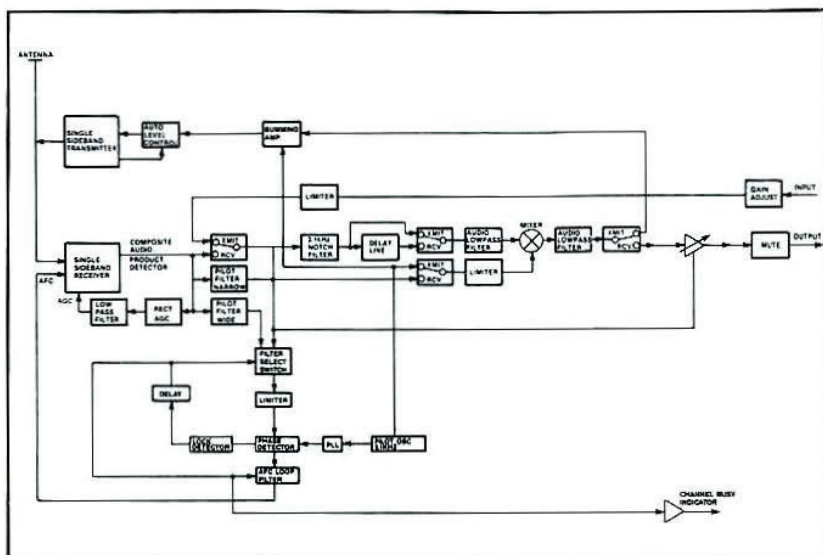


Figure 4. Block diagram of new circuits that process ACSSB signals to maximize data throughput. Synchronous frequency control eliminates received signal offset. Phase and amplitude effects caused by multipath fading virtually are eliminated in all but weak-signal conditions. The circuit uses the pilot tone as an artificial carrier during the modulation-demodulation process.

single-sideband radio system, using phase and amplitude correction circuitry, can send CPSK data without the usual irreducible error rate, achieving improvements in bit error rates of two orders of magnitude.

ACSSB, although still in its infancy, holds the promise of revolutionizing the radio industry. Its ability to convey both voice and data in extremely narrow bandwidth is well proven, and new techniques, soon to appear commercially, promise to increase its performance further, especially for mobile data.

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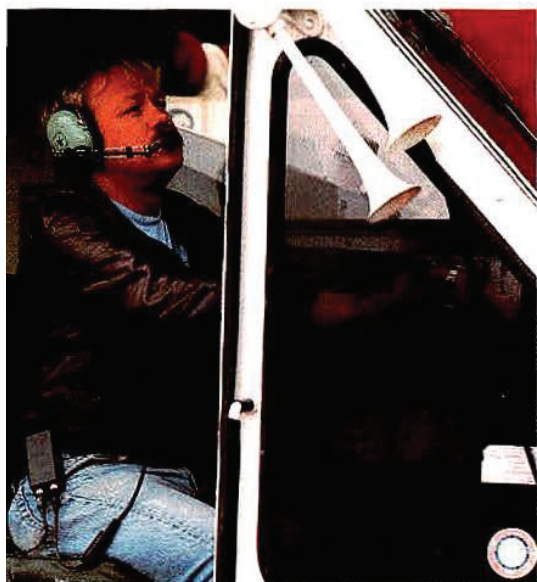
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