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Title: High-Performance UHF and Microwave System Primer, A

A High-Performance UHF and Microwave System Primer

Here's how you can get more out of your UHF/microwave station—*without* spending more money. If you're not already on these bands, here's how to get there, with respectable signals, for a lot less than you might expect.

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UHF and microwave operation is increasingly popular in the US and Canada. Using loop-Yagi antennas and KK7B/WA8NLC single-board transverters,[1,2] it's downright inexpensive and easy to get on these bands. UHF/microwave system performance suffers in many installations because dated or suboptimal techniques are used; many operators don't realize that major station improvements are possible by simply rearranging hardware they already own, and eliminating the particularly lossy system components. When you're first getting on the higher bands, you can save lots of money by following the recommendations I'll make in this article.

The major obstacle in any microwave system is feed-line loss.[3] In addition to the loss considerations, good feed line (such as Andrew Heliax) and matching connectors are expensive. A second, related problem is the availability of low-loss coaxial relays used for transmit/receive (TR) switching. As more amateurs become active on moonbounce and the UHF and SHF bands, the demand for these relays increases, and suitable surplus (read: *affordable*) units are hard to find. New coaxial relays are ridiculously expensive, especially when you consider that you need at least one for each band; a new Transco or K&L relay costs around $325!

What we need is a system whose good performance requires *neither* of these items.

Overcoming Feed-Line Losses

The loss of your feed line adds directly to the system noise figure (NF). Put simply (and ignoring added system noise), your 1-dB-NF GaAsFET front end becomes a 5-dB-NF device when you put a 4-dB-loss feed line between it and the antenna. At 903 and 1296 MHz, we can live with moderately long feed lines, but at 2304 MHz, a lossy feed line substantially impairs system performance. And at 3456 MHz and higher frequencies, feed-line losses are a major problem.

I won't get into the actual losses of various cables, as these numbers have been widely published elsewhere.[4,5] Certainly you should use the lowest-loss transmission line you can afford, no matter what the frequency. You should also keep feed lines as short as possible to reduce losses. Unfortunately, both of these factors sometimes dictate how high you can put the antenna system. It's even less desirable to use a 100-foot piece of feed line for a 75-foot run just because the cable came with connectors installed, and you don't want to cut the line because you're considering adding

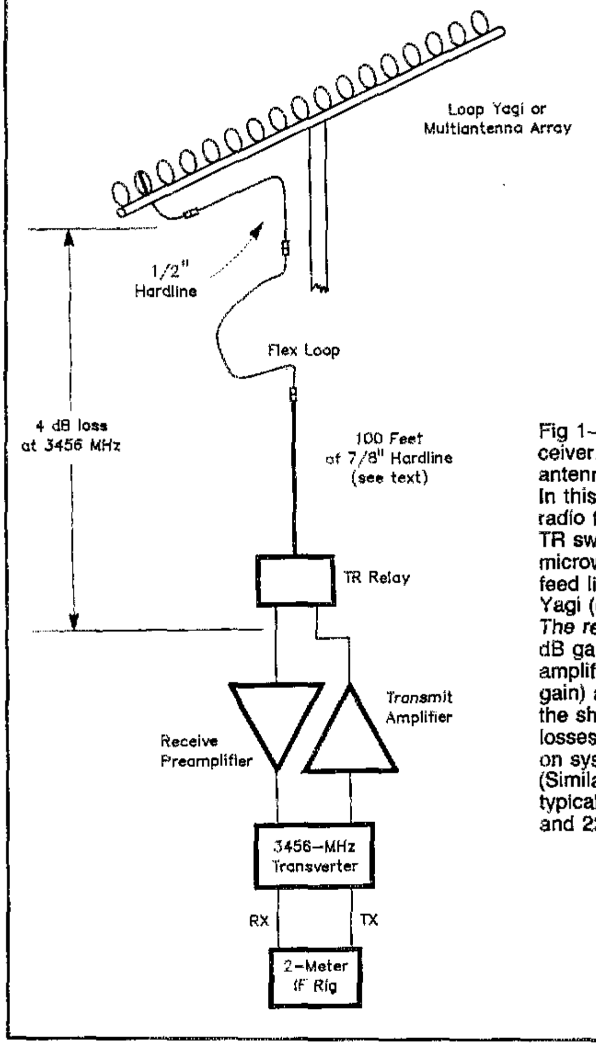

Fig 1—A typical IF transceiver, transverter, and antenna system for 3456 MHz. In this setup, a 144-MHz IF radio feeds a transverter that's TR switched through a microwave relay to a 4-dB-loss feed line and a single loop Yagi (or a multiantenna array). The receive preamplifier (50 dB gain, 1-dB NF), transmit amplifier (200 mW out, 13 dB gain) and relay are located in the shack, where feed-line losses take their greatest toll on system performance. (Similar systems are also typically used on 903, 1296 and 2304 MHz.)

[1]Notes appear on page 33.

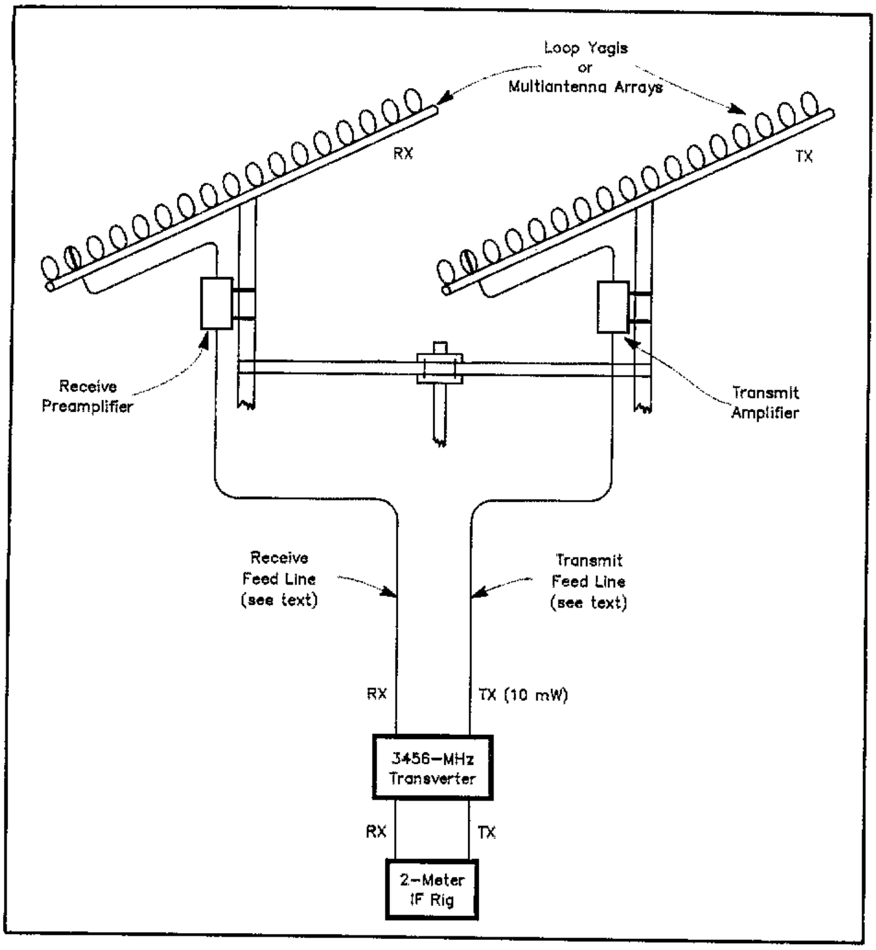

Fig 2—In this 3456-MHz station, separate antennas are used for transmitting and receiving. This allows the preamplifier to be mounted at the receiving antenna and the transmit power amplifier to be placed at the transmitting antenna. It also eliminates the need for an expensive microwave relay, and permits the use of inexpensive feed lines. The total cost and performance advantages of this system over a Fig 1 system are substantial.

a few tower sections in the future. Many of us do this at one time or another—I have. This is a real no-no at or above 2304 MHz.

Wouldn't it be nice if you could use almost any feed line, of any length, for the microwave bands? In most systems, there is a *viable* way to do just that.

A Typical Microwave System

The 3456-MHz installation shown in Fig 1 involves a single antenna system—either a single loop Yagi or an array of "loopers."[6] I'll talk about loop-Yagi antennas from here on, because they are inexpensive, more common than other kinds of 2304- and 3456-MHz antennas, and because they're more rugged (easier to keep in the air) than a dish. A single feed line connects the antenna to the station, and a low-loss coaxial relay switches the antenna between the receiver and the transmitter. The transmit amplifier and receive preamplifier are located in the shack.

Disadvantages of the Fig 1 system:

- It requires an expensive and hard-to-find low-loss microwave relay.
- It requires an expensive, high-quality, low-loss transmission line.
- Feed-line losses (4 dB) add directly to the system noise figure. As shown in Fig 1, the system NF is 5 dB (a 4-dB-loss feed line followed by a 1-dB-NF preamplifier).
- Feed-line losses reduce transmitter power at the antenna by 4 dB; 4 dB more power is required for the same ERP (effective radiated power) you'd get with a lossless feed line.
- Because of feed-line losses and cost, amateurs tend to keep antenna systems relatively low in height.
- Additional losses are incurred at the other end of the path when working a station with a similar system.
- It requires not only a low-loss main feed line, but also an around-the-rotator flexible loop and a low-loss cable from it to the antenna, plus the associated connectors.

Advantages of the Fig 1 system:

- All of its equipment can be kept indoors.
- There's no need to run power wiring up the tower.

Compared to the disadvantages, the advantages are hardly worth mentioning, because it's easy and relatively inexpensive to use waterproof housings and run power cables up a tower.

Another Approach: Using Separate Antennas

Now consider the two-antenna system shown in Fig 2. One antenna is used for receiving and the other for transmitting (each antenna may consist of a single looper or an array of two or more). Two feed lines are used, but no TR relay is needed. The receive preamplifier and transmit amplifier are mounted close to the antennas.

Advantages of the Fig 2 system:

- No expensive antenna relay is required—only the IF (usually 144 MHz) is switched.
- The preamplifier's noise figure (NF) works to maximum advantage because the preamplifier is mounted at the antenna, where there's no feed-line loss to degrade preamp NF. The system noise figure is close to that of the preamp.
- The antenna can be mounted as high as possible without regard to feed-line losses (as long as preamp gain overcomes the line loss).
- *No* expensive, low-loss transmission line is required, and no expensive connectors are needed. Flexible cables like RG-8, RG-213 and Belden 9913 (or equivalent) work just fine. RG-8, RG-213 and 9913 are the least expensive transmission lines you can practically use at 3456 MHz, and they work well at lower frequencies, too.
- Additional flexible coax loops and low-loss jumpers aren't required. Thus, fewer coax connectors are needed, and there are fewer joints to deteriorate and/or fail.
- Because feed-line losses aren't a factor, you get more ERP for a given amount of transmitter power.
- An improvement of *at least 8 dB* over a Fig 1 system can be realized when working a similarly equipped station.

The prototype 3456-MHz systems shown in Figs 1 and 2 use a receiving preamplifier (a modified TVRO unit[7]) with more than 50 dB gain, which is more than enough to overcome the loss in the coaxial cable that runs to the receiver. Even RG-8 or RG-213 cable can be used behind such a preamplifier. Higher-grade coax (Belden 9913 or equivalent) can also be used, and should be used with a preamp that has less gain than the TVRO unit. (At lower frequencies, this isn't as important.) Preamp power can be supplied externally or it can be fed through the coax to the preamplifier, as is commonly done in TVRO systems.

The transmit amplifier is mounted at the

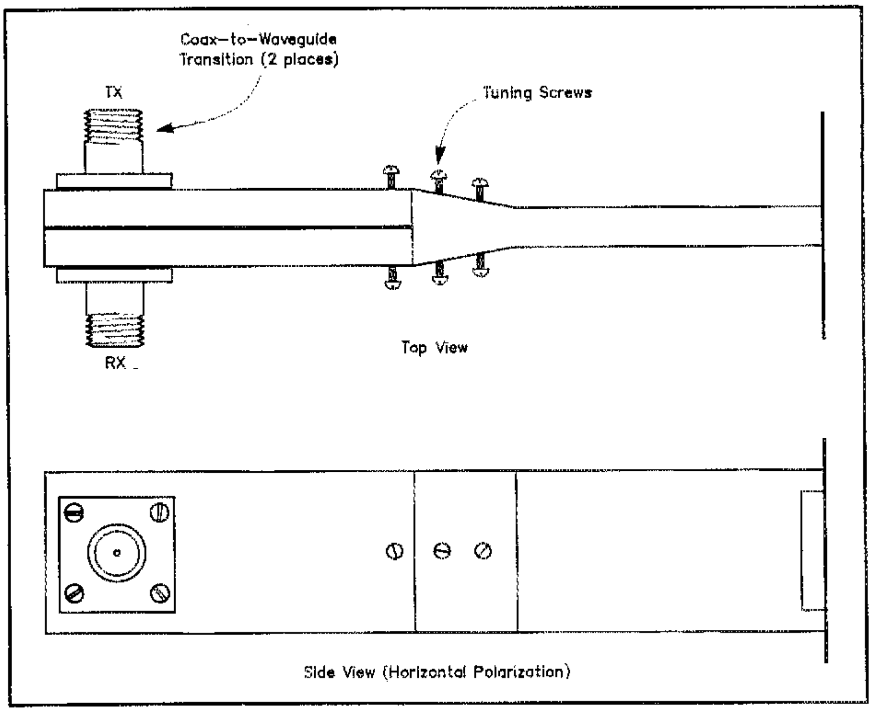

Fig 3—Separate-antenna systems aren't limited to loop Yagis or arrays of them: A single dish using a waveguide feed like this one, or a dual-polarization can feed, can serve just as well.

antenna, with an extra 10-dB-gain amplifier stage to make up for the feed-line loss. Take, for instance, a 200-mW amplifier with 13 dB gain, following your 3456-MHz no-tune transverter.[8] Mounting this amplifier at the antenna requires only an additional 10 dB gain before the final stage, which is easily supplied by a $10 MMIC amplifier at its input. This allows you to use 9913 coax as the transmission line.

Disadvantages of the Fig 2 system:

• Mounting equipment at the antenna requires watertight enclosures.

• You must run power wiring up the tower.

• A second antenna is required.

• Wider antenna spacing is needed. (The individual antennas in an array are closer together than is acceptable when separate antennas are used for transmit and receive, as discussed shortly.)

These disadvantages are some of the easier problems to overcome in a microwave system. Watertight enclosures are common and relatively inexpensive, as mentioned earlier. You have to run rotator cables and feed lines up your tower anyway, so one more small cable (per band) shouldn't pose a problem.

Installing a second antenna is not a major problem either. If you're serious about putting a good station on 1296, 2304 or 3456 MHz, then you are probably at least considering installing an array of two or four loop Yagis. If you use half of that antenna system on receive and the other half on transmit in a system like that shown in Fig 2, you'll increase your station's ERP *and* improve your receiving capabilities by more than the 3 dB you would get by doubling the size of your antenna. And you get several other bonuses (in addition to inexpensive feed lines, no expensive relay, etc).

Consider the two or four loop Yagis you were going to put up. You don't need a two-way power divider and phasing lines with the separate-antenna system. In an array of two loopers, the loop Yagis are usually mounted side-by-side in a Fig 1 system; they're mounted the same way in a Fig 2 system. Along the same lines, four loopers could be used in a separate-antenna system, as they would be for a quad array. A pair of antennas for receive would be mounted one above the other, and the pair of antennas for transmit would mount in the same manner.

Table 1
Microwave Station Performance Comparison

	Fig 1 System	Fig 2 System
Feed-Line Loss	4 dB	negligible
*Receive-System NF**	5 dB	1 dB
Transmit Power	200 mW	200 mW
Power at Antenna	40 mW	200 mW
EIRP†	4 W	20 W

*Assuming a 1-dB preamplifier noise figure.
†Effective radiated power with respect to an isotropic source, assuming 20 dBi antenna gain.

Two antennas for receive and two for transmit on an H frame in a Fig 2 system is better than a Fig 1, four-Yagi array. This arrangement gives almost 3 dB improvement on receive *and* on transmit because you've doubled the antenna size and saved several decibels of signal elsewhere by factoring out the losses in the feed line, relay and extra connectors.

One potential snag with separate-antenna systems is having the loop Yagis pointing in slightly different directions, but this is a problem only if the antennas are drastically misaligned. On the other hand, if the wind shifted your Fig 1 array on its mast, you'd also see a performance reduction. (In either situation, this mechanical problem can be eliminated by using struts mounted between the loop-Yagi booms, so that all the loopers move together with respect to the mast.)

In a Fig 2 system, the receiving and transmitting antennas must be spaced farther apart than they would be in a Fig 1 array. Three times the normal stacking distance provides reasonable isolation between the transmit and receive antennas. Because this type of system is geared toward low-power, solid-state transmitters, transmit power picked up by the receiving antenna is quite low, even if you're lucky enough to have a few watts at the transmit antenna. (I've intentionally put many milliwatts of RF directly into an unpowered 3456-MHz GaAsFET preamp without damage.) Good amateur practice dictates that a preamplifier's power supply should be disconnected during transmit in any system.

Performance

Table 1 shows, in a numerical summary, the sizable improvement in station performance with a Fig 2 system. In this discussion and in Table 1, I've ignored external receiver-system noise, which has about the same relative influence on switched- and separate-antenna systems.

If two 3456-MHz stations using Fig 1 systems with 200-mW transmitters converted their stations to the Fig 2 configuration, they could work each other with comparable signals using only 10-mW transmitters. A transmitting station running 10 mW to such an antenna has an ERP of 1 W, and the receiving station has an additional 4 dB of receive-system sensitivity. This means that you could use a 10-mW transverter, RG-8 for both feed lines, a modified TVRO preamp for receive and another as a 10-mW-output transmit amplifier, and work other stations on 3456 MHz SSB.

Solutions for Dishes

The separate-antenna technique works well on 3456 MHz and lower frequencies using loop Yagis at home stations and in portable operation. Using separate receive and transmit antennas allows portable antennas to be mounted higher without concern for feed-line loss, less transmitter power is required for the same coverage and less dc power is needed, because there's no power-hungry relay to energize.

On the higher bands (5760 MHz and up), where dish antennas are used almost exclusively, most operation is done at mountain-top locations. You can make dish feeds using dual-polarization feed systems with two orthogonal probes. This makes a single dish into two antennas (and guarantees that both antennas are on the same beam heading!). The fixed station could transmit with, say, horizontal and receive with vertical polarization; the rover station(s) would receive horizontal and transmit vertical polarization.

Walt Bohlman, K3BPP, gave me another idea for a separate-antenna system using a dish. Walt suggested making a feed using two pieces of waveguide tapered to a single piece that extends to the dish focus, as shown in Fig 3. Although I haven't tried this, it seems to be a way to get same-polarization receive and transmit from one reflector without TR switching. The focus end of the feed, as well as the transmit and receive ends, would be terminated in waveguide-to-coax transitions. Tuning screws mounted at the Y point would serve to tune the assembly for minimum loss and best isolation between the transmit and receive ports. The single end would then be cut off, and the slotted feed/splash plate[9] fabricated. I'm interested in hearing from anyone who tries this.

Again, the antennas can be mounted as high as possible without regard to feed-line losses. For temporary installations (such as mountaintop stations), the complete transverter system can be mounted on the rear of the dish using short pieces of cable to the feed. A piece of RG-58 cable from the IF radio to the antenna-mounted units would work well, no matter how high the antenna is mounted.

Summary

At microwave frequencies, where high transmitter power is relatively hard to come by (and expensive), it's to our advantage to use separate antennas to cut costs, improve station performance and help increase the populations of the UHF and microwave bands.

For amateurs who are fortunate enough to have high-power TWTAs (traveling-wave-tube amplifiers), the conventional low-loss transmission line (or waveguide) is still needed. There's no reason, however, why a separate-antenna system couldn't also be used. The advantages of having the receive preamplifier at the antenna and no need for an antenna relay still makes this high-performance system practical and useful.

It is now possible for the average ham, running only milliwatts, to make contacts on the higher UHF and microwave bands. I find this kind of operation more challenging and more fun than VHF/UHF communications, as do many of the growing numbers of hams getting on these bands. Give it a try!

Notes

[1]Rick Campbell, KK7B, and Jim Davey, WA8NLC, have collaboratively designed single-board, no-tune transverters for the 903- through 5760-MHz amateur bands. See the following articles on these transverters:
• R. Campbell, "A Single-Board No-Tuning 23 cm Transverter," *Proceedings of the 23rd Conference of the Central States VHF Society* (Newington: ARRL, 1989), pp 44-52.
• J. Davey, "No-Tune Transverter for 2304 MHz," *Proceedings of Microwave Update '89* (Newington: ARRL, 1989), pp 30-34.
• J. Davey, "A No-Tune Transverter for 3456 MHz," *QST*, Jun 1989, pp 21-26. Also see Feedback, Oct 1990 *QST*, p 31.
• R. Campbell, "A Single-Board Bilateral 5760-MHz Transverter," *QST*, Oct 1990, pp 27-31. This article lists, in its end notes, sources for lots of information on microwave antennas and other subjects of general interest.
The *Proceedings* books are available from ARRL for $12 each plus $2.50 shipping and handling. A *QST* article by Rick Campbell on the 903-MHz version is forthcoming.

[2]Loop-Yagi antennas and KK7B/WA8NLC 10- to 20-mW, single-board, no-tune transverters are available from Bill Olson, W3HQT, Down East Microwave, RR 1, Box 2310, Troy, ME 04987, tel 207-948-3741. Catalog available.

[3]In this context, the feed line includes the jumper connected to the antenna, the cable around the rotator (the "flex loop"), the main transmission-line run, the antenna relay and the jumpers connecting the receiver and transmitter to the relay.

[4]B. Olson, ">50," *QEX*, Aug 1987, pp 15-16.

[5]L. Wolfgang and C. Hutchinson, eds, *The ARRL Handbook* (Newington: ARRL, 1990), pp 16-14 and 16-15.

[6]See note 2.

[7]B. Atkins, "The New Frontier," *QST*, Aug 1987, p 59.

[8]See notes 1 and 2.

[9]B. Atkins, "The New Frontier," *QST*, Dec 1987, p 64.

ESD—*Part 2*

(continued from page 29)

of this reference, most of the basic ESD supplies can be obtained from the suppliers listed below:

Wrist Straps & Work Mats

Hub Material Co, 33 Springdale Ave, Canton, MA 02021, tel 800-482-4440 (617-821-1870 in MA).

Jensen Tools Inc, 7815 S 46 St, Phoenix, AZ 85044, tel 602-968-6231.

MCM Electronics, 650 Congress Park Dr, Centerville, OH 45459, tel 513-434-0031.

Specialized Products Co, 2117 W Walnut Hill Ln, Irving, TX 75038, tel 800-527-5018.

Conductive Foam

Hub Material Co, 33 Springdale Ave, Canton, MA 02021, tel 800-482-4440 (617-821-1870 in MA).

MCM Electronics, 650 Congress Park Dr, Centerville, OH 45459, tel 513-434-0031.

Specialized Products Co, 2117 W Walnut Hill Ln, Irving, TX 75038, tel 800-527-5018.

Antistatic Coatings

ACL Inc, 1960 E Devon Ave, Elk Grove Village, IL 60007, tel 312-981-9212.

Charleswater Products, Inc, 93 Border St, West Newton, MA 02165, tel 617-964-8370.

Hub Material Co, 33 Springdale Ave, Canton, MA 02021, tel 800-482-4440 (617-821-1870 in MA).

Tech Spray, PO Box 949, Amarillo, TX 79105, tel 800-858-4043.

Antistatic Packaging

Hub Material Co, 33 Springdale Ave, Canton, MA 02021, tel 800-482-4440 (617-821-1870 in MA).

Maine Poly Inc, PO Box 8, Greene, ME 04236, tel 207-946-7440.

Plastic Systems, Inc, 261 Cedar Hill St, Marlboro, MA 01752, tel 508-485-7390.

Republic Packaging Corp, 9160 S Green St, Chicago, IL 60620, tel 312-233-6530.

Specialized Products Co, 2117 W Walnut Hill Ln, Irving, TX 75038, tel 800-527-5018.

Static Inc, Old Sherman Tpk, Danbury, CT 06810, tel 203-791-3600.

Ionizers

Corion Technologies, Inc, 215 Salem St, Woburn, MA 01801, tel 617-933-8558.

Hub Material Co, 33 Springdale Ave, Canton, MA 02021, tel 800-482-4440 (617-821-1870 in MA).

Ion Systems, Inc, 2546 Tenth St, Berkeley, CA 94710, tel 415-548-3640.

Simco Company, Inc, 2257 North Penn Rd, Hatfield, PA 19440, tel 215-822-2171.

Semtronics, PO Box 94, Oldwick, NJ 08858, tel 201-534-5196.

Antistatic Tools

Jensen Tools Inc, 7815 S 46 St, Phoenix, AZ 85044, tel 602-968-6231.

Antistatic Apparel

Oak Technical, Inc, 219 S Sycamore St, Ravenna, OH 44266, tel 216-296-3416.

Prudential Overall Supply, 6948 Bandini Blvd, Los Angeles, CA 90040, tel 213-722-0636.

Workton, 10099 Seminole Blvd, Seminole, FL 34642, tel 800-727-8643.