

Reinventing antennas

An effort to design a wideband antenna for trunking leads to an interesting new tool for multiple applications.

By Don Simon and Jack Daniel

Every now and then, a truly new concept comes along. This antenna is a major innovation.

Dan Kaegebein, principal engineer and one of the founders of TX RX Systems, sought to develop an antenna that would match the broadband capabilities of his patented "T-Pass" transmitter combiners.

Although the unit can combine channels over frequencies ranging from 800MHz to 960MHz into a single transmission line, there were no high-performance gain antennas that could match this wide bandwidth. This new antenna design is flat from 806MHz to 960MHz.

While trying to solve the bandwidth problem, Kaegebein created an antenna with secondary features desirable for most systems operating in the 800/900MHz bands.

We will use the 806MHz-to-960MHz

wideband, 8dB-gain, omnidirectional antenna as an example.

Corporate-fed arrays

The new antenna uses "corporate (parallel) feed" to drive its eight vertically stacked dipoles, as shown in Figure 1 at the right.

Corporate feed distributes power equally to all elements, which allows for a wide beamwidth. However, it is difficult to construct antennas using corporate feed. The familiar folded-dipole arrays are the most common example. Unfortunately, all of the cable connections are exposed to the weather with predictable results. The new antenna uses internal feed lines protected from the elements by a radome instead of coaxial cable harnesses.

Series-fed arrays

The most common stacked vertical arrays are "series-fed" as shown in Figures 2A and 2B.

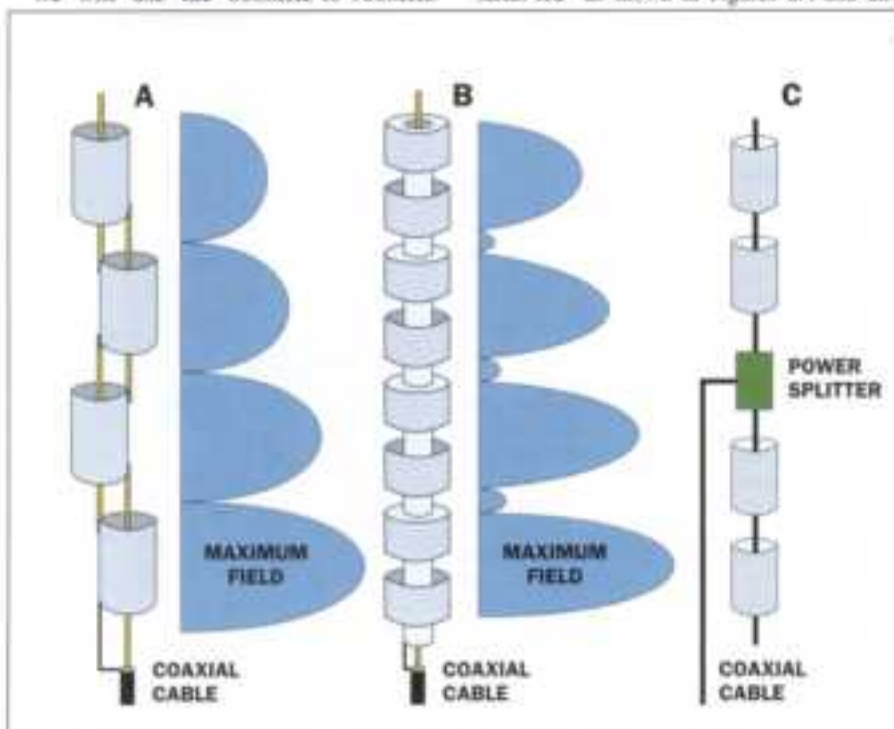


Figure 2. Series-type feeds.

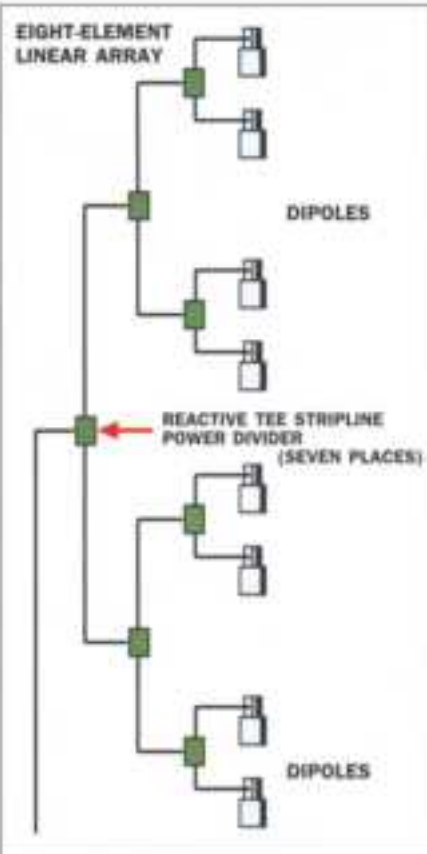


Figure 1: Corporate feed diagram.

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Transmit power is coupled to each dipole in sequence. This approach eliminates internal cabling. However, as the power is divided down, each dipole is less effective than the preceding one.

To improve the E-Plane (vertical) pattern in a series-fed antenna, elements must be added to produce gain equivalent to that of a corporate-fed design. Adding elements increases the overall length, which magnifies wind, vibration and ice loading effects. Mechanical stability is difficult to maintain, and a shortened life is common. Longer arrays suffer increased tip deflection, which translates into more frequent "pattern deflection" problems.

The physics of coupling relationships makes building series-fed antennas with more than 15MHz of bandwidth difficult. This translates into more feed lines, antennas and site leases than we might like.

Pattern scanning

"Pattern scanning" is another problem for services with 45MHz transmit-to-receive splits in the 800MHz and 900MHz bands. Most series-fed antennas are designed for minimum "return loss" (VSWR) at the transmit frequency. However, this means the phase relationships at the receive frequency are not right. As a result, operating below the center frequency causes pattern down-tilt, while operating above the center frequency causes up-tilt. All of this leads to some interesting imbalance issues between the antenna performance on uplink vs. downlink.

Users have found at least one novel approach to reduce the effect of pattern scanning by feeding a splitter located in the center of the antenna and then series-feeding the elements above and below the splitter, as shown in Figure 2C. This allows the two halves of the antenna to act against each other to reduce scanning, but this may make the beamwidth of the antenna vary across the band.

Truly vertical antenna mounting, mechanical stability (i.e., tip deflection) and tower deflection become critical when scanning is combined with narrow beamwidths.

Pattern deflection

Popular high-gain, series-fed antennas have narrow beamwidth (typically $\pm 3.5^\circ$ at zero down-tilt). The combined effects of wind, ice, tip deflection, tower sway and mounting errors can lift the pattern off the ground, causing call drops during high wind. Pattern scanning just makes it worse.

Gain antennas reduce the beamwidth of an antenna, and the main power lobe can become quite small. For example, one well-known 9dB gain antenna has a ± 3.5 dB beamwidth of 8° , meaning that the main beam power will be concentrated $\pm 3.5^\circ$ above and below the horizon, assuming the standard 0° down-tilt version. If the tip of the antenna is deflected from a true vertical position by 3.5° , the signal will drop in two directions (the direction of the tilt and its opposite direction) by 3dB.

The combined effects of high winds, ice loading, tower sway and mounting error all contribute to this problem. The problem is compounded when the scanning effect of older antenna designs is included.

The new antenna design minimizes this problem. The antenna tip deflection is only 0.5° in a whopping 225mph wind, and the beamwidth is increased to 10° . The massive internal mast extrusion, short length (9.5 feet total for 8dB gain) and the 0.22-inch-thick fiberglass radome serve to make the antenna strong and rigid.

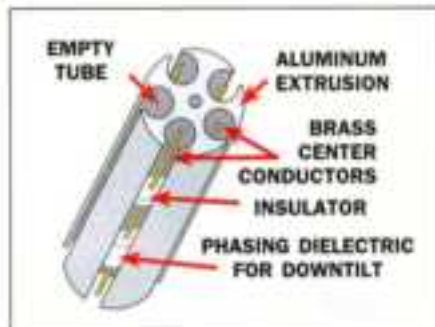


Figure 3. Mast perspective view.

Corporate feed system

Figure 3 illustrates the new method of implementing corporate feed in the antenna. The center mast of the antenna has five precisely extruded and machined tubes extending the full length. When a brass center conductor of the proper diameter is centered in these tubes, they become perfect air dielectric coaxial lines.

The clever use of low-loss air dielectric transmission lines matches the phasing characteristics of the broadband dipole elements, so there is an inherent mechanical match between the components. This makes the transmission line length equal to the dipole feed points. If ordinary coaxial cables were used, the propagation rates would be different, and mechanically matching the lengths would be nearly impossible.

Downtilt

Even the manner in which the antenna achieves downtilt is different. The designer placed a predetermined length of dielectric around the feed transmission line to the dipole, as shown in Figure 3. This changes the propagation of the transmission line, and therefore the phasing, between the dipoles. The length, not the position, of the dielectric insert determines the amount of downtilt. Existing antenna designs are for 3° and 5° . Other angles should be easy to produce.

The extruded mast also provides most of the mechanical strength and stability, extending the full length of the antenna. This huge cross-section is an excellent low-resistance ground for the antenna. Lightning-induced failures should be rare.

Bandwidth improvements

The bandwidth of an antenna is primarily determined by frequency-sensitive coupling components and the diameter-to-frequency ratio of the dipoles. True coaxial mounting allows the dipoles in the new antenna to be many times larger than most early antenna designs, contributing to the record bandwidth. The use of air-line coupling virtually eliminates frequency sensitivity.

Reactive "T" power dividers required in the new antenna are constructed as shown in Photo 1, note A, at the left. The power dividers are of a broadband stripline design with low loss. The power divider is gold-plated to eliminate corrosion and intermodulation.

The dipoles shown in Photo 1 are arc-welded at all points for maximum mechanical strength and to eliminate any intermodulation due to corroded or broken joints, loose screws or any of the other common intermodulation sources. There are no metal screws connecting any conducting circuit in the antenna.

Power handling

The antenna is capable of handling 1,000W continuous input, allowing use with large SMR and paging combiners.

Mechanical considerations

Based on prior antenna construction and improved testing methods using antenna network analyzers, many system operators now assign an arbitrary antenna life of 18-24 months.

Most series-fed antennas derive their strength and wind/vibration resistance from the radome. The internal parts take a beating as the radome flexes and vibrates in the wind. The small internal joints fail from work-hardening of the materials, there is dissimilar metal corrosion, and jumpers are blown by high lightning currents.

Applications

The new antenna is suited for rural cellular and SMR applications. Matching uplink and downlink patterns that assure hand-held coverage and fill will be consistent, with fewer dropped calls and reorders. The wide vertical beamwidth of the antenna will prevent pattern lifting and call drops during wind storms. The pattern will stay on the ground with the mobiles.

Paging operators will be able to combine operations at 902MHz, 929MHz-931MHz and 940MHz. Additional dual-antenna models are forthcoming in various combinations to reduce site rental costs.

Site operators will find the 806MHz-960MHz bandwidth of the antenna useful on master receiver multicoupler systems. ■

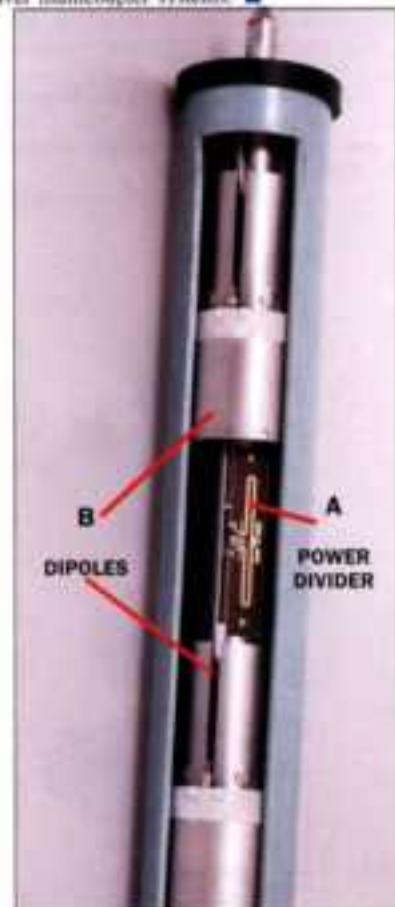


Photo 1. Cutaway view of the antenna.