Weak signal VHF/UHF operators have probably missed more contacts because of improper polarization than any other single cause. Here's what it is and what you can do about it.

Circular Polarity with Linear Antennas

BY JOHN QUINN*

Over the years, at both HF and VHF, linear antenna polarization has been used almost exclusively. At VHF, antenna polarity was often divided between vertical polarization, used mainly for FM/Repeater use, and horizontal, used for long haul CW/SSB. The main advantages to vertical polarization is the ease of obtaining electrical separation of transmitting/receiving antennas at repeater sites, and the simplicity of mobile antennas. It may be that for long haul VHF operation, horizontally polarized signals suffer less from polarization shifts than vertically polarized signals. The advantage of horizontal polarity over vertical polarity for such operation is an arguable point.

With either vertical or horizontal polarization, some polarity distortion will occur between the transmitting and receiving stations. The degree of rotation will depend upon frequency, terrain and distance. Any such rotation of the transmitted signal will result in decreased signal capture at a linear receiving station. The solution is to use circular polarization at both the transmitting and receiving sites. Provided that both stations are using the same polarization sense, i.e. right-hand circular or left-hand circular, then all the available energy at the receiving site will be captured by the receiving antenna.

Until the advent of space communications, specifically satellite communications, little thought was ever given to the phenomena. Space communication however demands a re-think of this whole situation. Control of polarization of a signal emanating from a spinning satellite is difficult if not impossible and circular polarization has become the accepted standard. Other space communication applications also benefit from circular polarization. As frequency of operation increases, it is not uncommon for moonbounce operators to observe a phenomena known as Faraday rotation. This propagation phenomena is really an extreme of the rotational distortion that is evident on long terrestrial paths. However, moonbounce operation is a marginal art, and if linear polarization is used at both transmitting and receiving sites, it is not uncommon for the bounced signal to suffer such a high degree of rotational distortion as to be un-copyable at the receiving site, even though calculations regarding path loss, transmitter power and receiver performance indicate that contact should be possible. Clearly, circular polarization at both transmitter and receiver will eliminate this problem. One point to note however is that circularity reversal occurs as the signal bounces off the moons surface. That is, a signal arriving with clockwise circular polarity at the moons surface, will produce a bounced signal with counter-clockwise polarity.

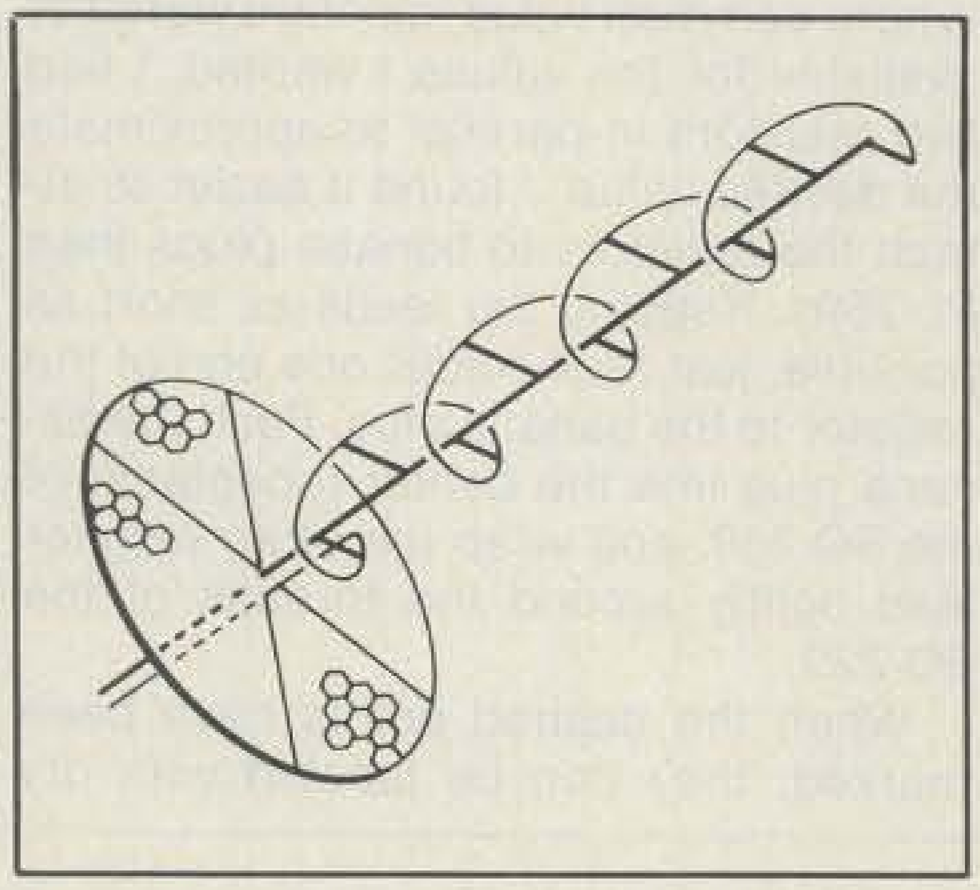

Fig. 1–A typical home-made helix antenna constructed on a wooden pole with a "chicken wire" reflector.

Achieving Circular Polarity

There are two common antenna designs for producing circular polarization: the helix and the crossed Yagi.

The helix antenna, fig. 1., is probably the most simple form of high gain, circular antenna, but it suffers from one major problem. The polarization sense of a helix is determined by its construction. If the antenna is wound as a right hand thread form, then the antenna will exhibit right hand circular polarization. Conversely, a left hand thread form will produce left hand circular polarization. Such an antenna would be fine if all signals to be received were of known polarity but moonbound operation for example, one would require a separate antenna for both transmit and receive. Considering the huge antenna arrays necessary for moonbounce operation, this is clearly impracticable.

The crossed Yagi, fig. 2A, is the most common form of circular antenna in use for the VHF/UHF bands today. It offers high gain for it's length combined with switchable polarity (circularity sense). This form of antenna will provide excellent performance at both 144 and 432 MHz bands. The crossed Yagi is nothing magical. It is simply two completely separate Yagi antennas, one horizontal, the other vertical, which just happen to share a common boom. It is in the method of combining these two antennas that the propagation mode is determined. At lower frequencies, with only a few elements, both horizontal and vertical antennas may be constructed on a common boom with little interference, either mechanically or electrically. At higher frequencies, i.e. 432 MHz and above, this becomes increasingly difficult for two reasons.

First, higher frequency operation demands higher gain antennas. With Yagi designs, this equates to more elements, and thus to a greater chance of mutual mechanical interference between the vertical and horizontal antennas.

Second, as frequency increases, the absolute dimensions of elements decreases but the physical size of driven structures, baluns and cables remain large. Therefore, it is impossible to design a crossed Yagi for 1296 MHz for example, without suffering performance

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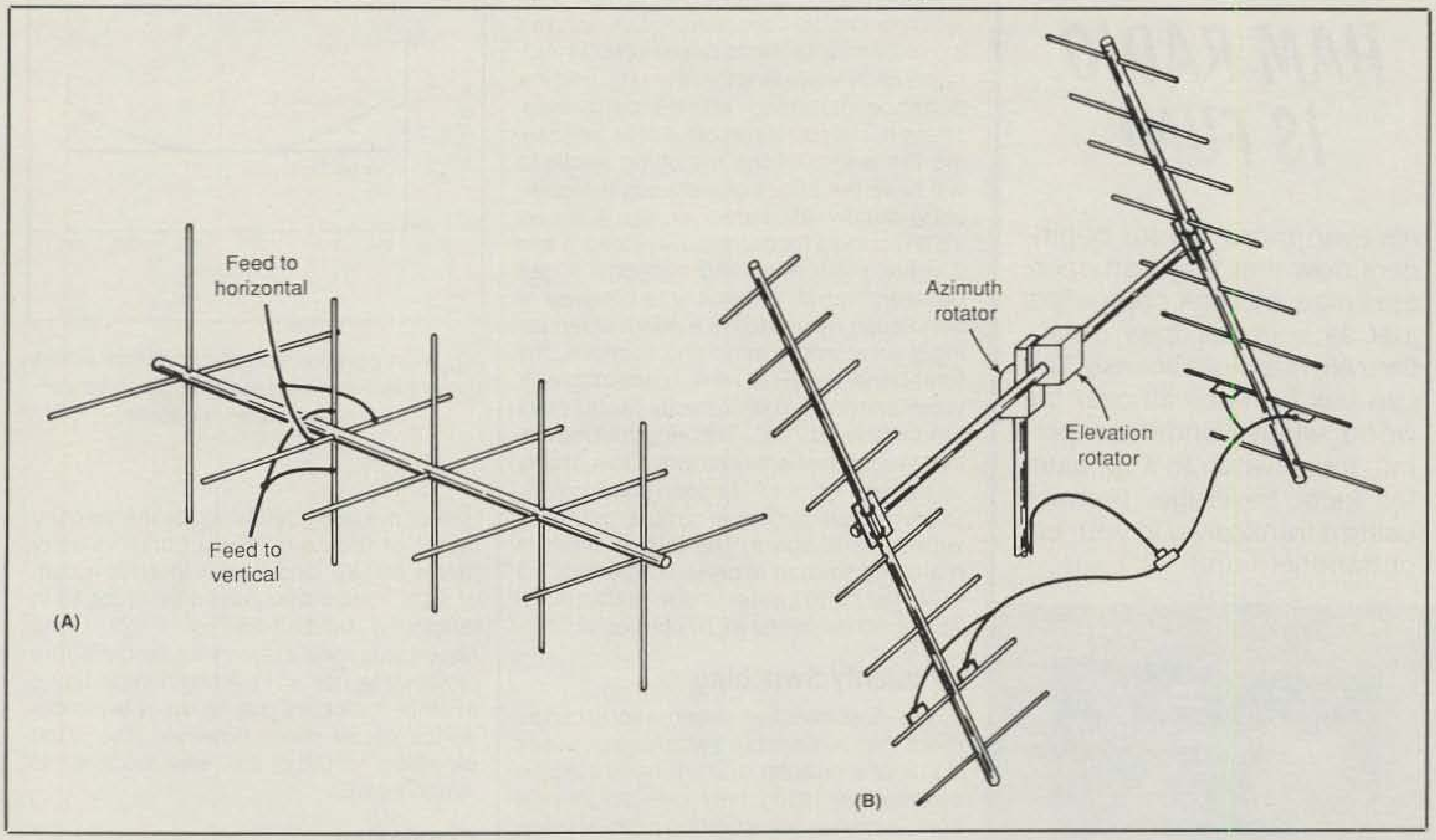


Fig. 2– At (A), a crossed Yagi with both antennas mounted on the same boom. At (B), a second version of the crossed Yagi with each antenna having its own boom. In both cases, the planes of the elements are perpendicular to each other.

degradation. An attempt to combine two 18 dB linear Yagis on one boom might result in circular antenna with poor circularity and several dB down on expected gain performance. Not exactly state of the art.

Remember we decided above, "the crossed Yagi is nothing magical." Why not construct two separate linear Yagis. Have one vertical, the other horizontal, combine them and produce a circular beam in this way. (fig. 2B).

Well, at 1296 MHz, this is indeed the optimum approach. After all, all that is required extra over a crossed Yagi design, is one more boom. At 1296 MHz, that is no big deal!

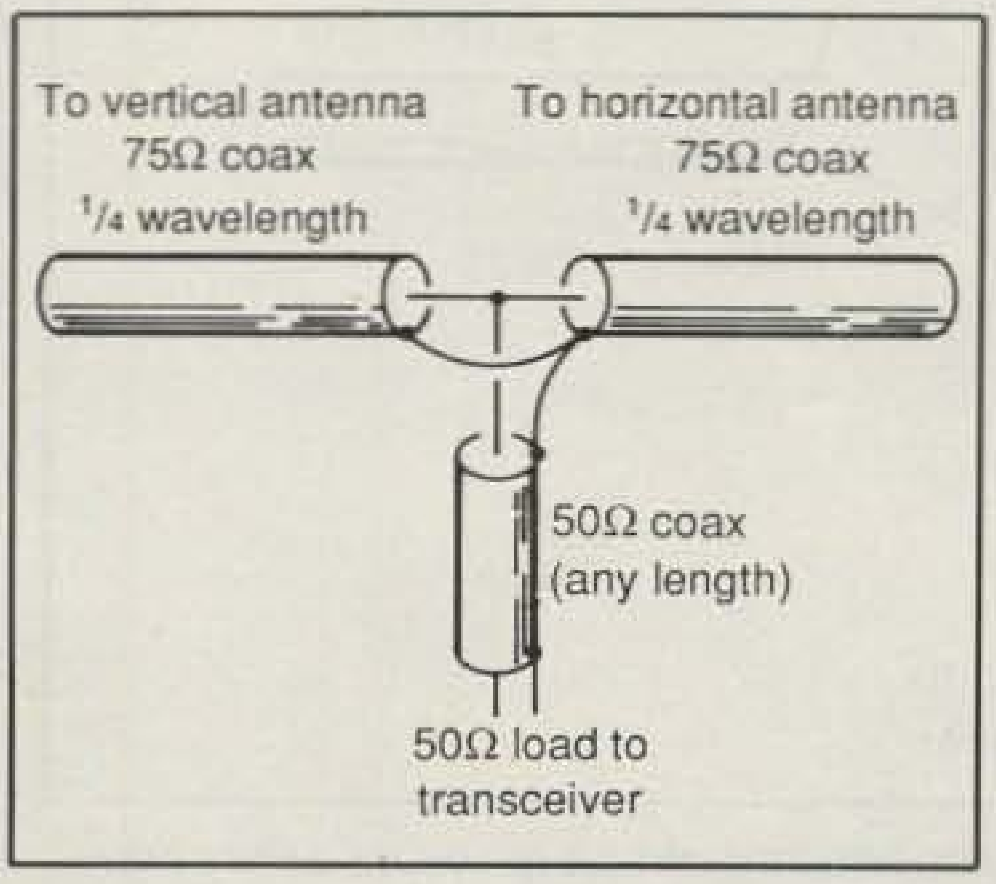


Fig. 3– A "T" connection for matching the two antennas to 50-ohm coax.

Before attempting to combine two antennas as above, it is necessary to understand how circularity control is achieved. Basically, to combine two Yagi antennas to form one circular antenna, two things are required. In order to maintain a 50 ohm drive impedance, some form of a matching network is required.

Second, to produce a circular wave front, either one antenna must be physically ¼ wavelength behind the other, or the signal to one antenna must be delayed by ¼ wavelength in time.

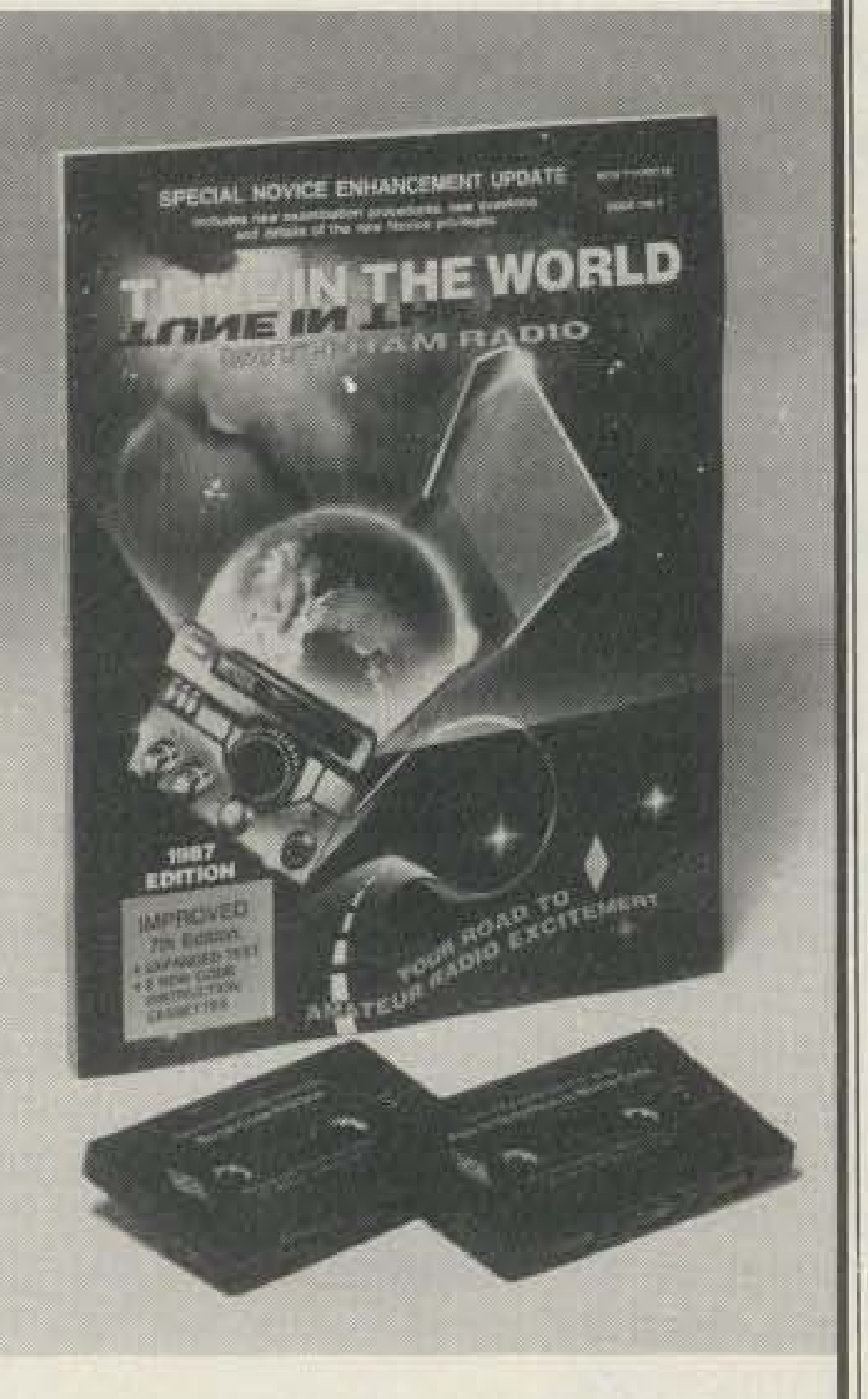
Typically, matching is achieved by the circuit in fig. 3. In this circuit, each antenna has a 50 ohm impedance. A ¼ wavelength coaxial line section acts as an impedance transformer, raising this impedance to 100 ohms. At the 100 ohm point, both are simply combined again to produce the desired 50 ohm characteristic impedance. Theoretically, the impedance of each matching section should be 70.7 ohms, however, the slight mismatch due to the use of standard 75 ohm coax is minimal.

In order to produce the desired circular wavefront, it is usual for crossed Yagi antennas to have one set of elements mounted ¼ wavelength in front of the other with respect to the rear of the boom. If the two antennas are now combined as above, the circularity sense of the combined antenna will be determined by the polarity of the driven dipoles of each separate antenna. In order to switch circularity sense, all that is required is to insert a ½ wavelength delay in the feed to the front-most set of elements. The effect of inserting ½ wavelength is to nullify the ¼ wavelength mechanical advancement of the front-most set of elements and to further delay it's signal by an additional ¼ wavelength thus electrically making this antenna the rearmost one.

The above techniques for combining and phasing two antennas, one horizontal, the other vertical, will work èqually well whether a single or twin booms are used. If totally separate antennas are used, as in the 1296 MHz example above, one modification to the above technique is required. Using cable with a velocity factor of 0.66, ¼ wavelength at 1275 MHz is 1.529 inches, or a total of 3.058 inches between antennas. Clearly we have a problem.

There are two solutions. We can extend the ¼ wavelength 70 ohm matching section by inserting a length of 50 ohm cable between the matching section and the antenna feed point. Or we can increase the length of the matching section to an odd multiple of quarter wavelengths.

Clearly, the first solution is the less desirable as the transition from the 70 ohm cable to the 50 ohm cable is just one most point at which losses can occur. The se-



cond solution is preferred as no additional discontinuities are required. As long as the matching sections are exact odd multiples of ¼ wavelengths, the required impedance matching will be performed. There is a small trade-off in that increasing the length of the matching sections will have the effect of reducing the operating bandwidth. However, fig. 4 shows VSWR curves for both ¼ wavelength and 7/4 wavelength matching sections. It can be seen that although a small degree of band edge mismatch is evident when using 7/4 wavelength matching sections, the total-band VSWR is very respectable. 7/4 wavelengths of 0.66 velocity factor coax amounts to 10.703″. This length of matching section per antenna will allow antenna separation of 12″ (a good stacking distance for producing a circular pattern), with cable to spare. The failure of either matching section to provide a perfect 1:1 VSWR at band center is due to the use of 75 ohm coax in lieu of 70 ohm coax.

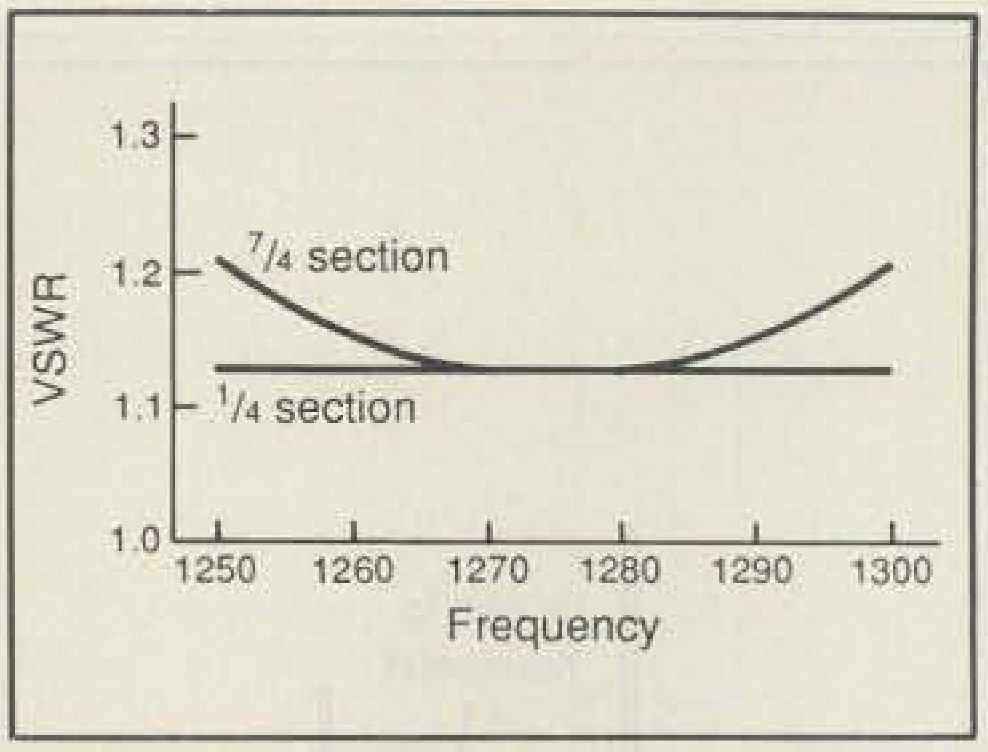


Fig. 4– A comparison of bandwidth when using 7/4-wavelength matching cables versus ¼-wavelength cables.

Circularity Switching

Fig. 5 shows the schematic arrangement that will enable switching between right-hand circular and left-hand circular polarization using only one single-pole double-throw, non-shorting coaxial relay. When in circuit, the 50 ohm ½ wavelength aection serves to delay the signal to the front-most antenna by 180 degrees. When switched out of circuit, this section presents a half-wavelength open circuit stub at the operating frequency and thus has little effect. All connections to the coaxial relay should be as short as possible. The 7/4 wavelength section to the front-most antenna should be reduced in length by the length of the internal structure of the relay, allowing for the velocity factor of the coax. For a cable velocity factor of 0.66, and a relay internal length of 1.25″, the cable should be reduced in length by 0.66, 1.25″ or 0.825″. The above assumes a relay with air dielectric (velocity factor = 1). A slight impedance mismatch occurs due to the relay impedance of 50 ohms however, the short electrical length of the relay renders this insignificant.

Conclusion

Overall, circular polarization is the preferred polarization scheme for both terrestrial and space communications. At frequencies above 450 MHz, superior performance may be obtained using correctly phased individual horizontal and vertical Yagis. Combining/matching may be achieved using odd multiples of ¼ wavelength coaxial cables and standard connectors. CQ

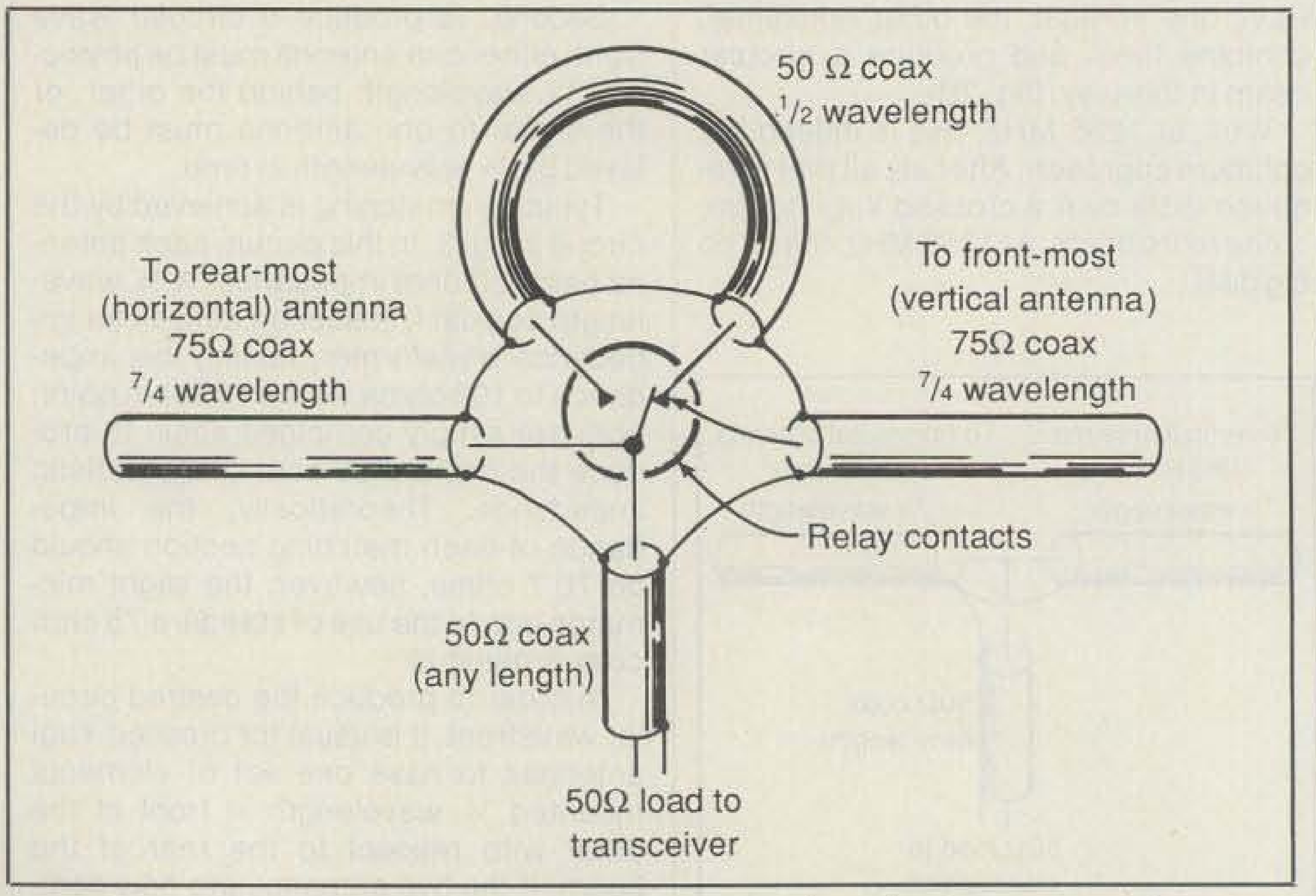


Fig. 5– Relay for switching ½-wavelength delay line into circuit to reverse the polarization sense. See text for specifications.