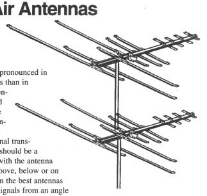
Stacking Winegard® Off-Air Antennas

For improved directivity, stacking antennas can significantly reduce or eliminate most types of off-air television interference.



Multiple outdoor television antenna arrays, reminiscent of the 50s, are making a comeback in some areas. Proper stacking of the sophisticated off-air antennas of today significantly improve reception, boosting directivity and selectivity as well as gain. Stacking eliminates a lot of reception problems found with multiple high-rise buildings and heavy users of electrical power, both of which cause television interference (TVI) problems. Typical TVI problems (ghosts, electrical noise, interfering radio signals, picture breakup) can also be caused by ground reflections, moving reflectors such as trucks and airplanes, and ignition noise. Stacked antennas will overcome many of these reception problems.

Winegard Chromstar® and Prostar® off-air antennas are designed to provide high gain, sharp directivity and excellent front-to-back ratio on a single VHF TV channel. These Yagi-type antennas are adaptable for stacking — horizontally and vertically. This type of antenna, the most commonly used type for television reception, "sees" electromagnetic radio waves in a manner similar to the way we see. Our eyes see in the general direction we point our head. And the antenna "sees" in the general direction in which its boom is pointed. Viewed from the top, a Yagi-type antenna resembles an arrowhead, tapering from front to rear (figure 1).

Figure 1

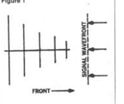


Figure 1: Top view of typical Yagi antenna.

This taper is more pronounced in broadband antennas than in single channel antennas. The arrowhead (narrow end) of the antenna should, generally, point in the direction of the signal transmitter. Ideally this should be a straight-line path, with the antenna "seeing" nothing above, below or on either side, but even the best antennas "see" undesirable signals from an angle off the axis of the antenna. These signals can cause ghosting and other interference patterns.

A Yagi-type antenna is designed with many parallel elements on a common axis, oriented toward the signal source. Length, spacing and phasing of each element in relation to others determines how voltages introduced in individual elements reinforce (add) at the antenna terminals. The elements are arranged and spaced so the signal wavefront reaches each element *sequentially* — and the voltage induced in each antenna element combines at the antenna terminals with voltages from the other elements to yield an optimized voltage which produces maximum gain over the desired bandwidth.

If the signal comes from a source *above* or *below* the horizontal plane of the antenna, *all* elements receive it at the same time instead of sequentially. Under these conditions, the combined voltage at the antenna terminals will be something less than the optimum for which the antenna was designed.

Vertical Stacking

Vertical stacking improves both gain and vertical directivity. This helps reduce airplane flutter and attendant picture roll, plus certain types of ground noise and ground reflections

Stacking two identical antennas on a common vertical mast significantly (30%) narrows the *vertical* beam-width angle. Vertically stacked antennas reject the interfering signals *above* or *below* their horizontal plane more effectively than a single antenna. It's as though they were looking through a mini-blind. Because there's nothing mounted to the side of either antenna, their horizontal vision is virtually uneffected. In the process, gain increases about 2.5 dB over that of a single antenna.

The basic principle of stacked antennas involves the difference in the time of arrival, and therefore the phase, of signals intercepted by the antenna combination. If a pair of identical Chromstar antennas are mounted one above the other a wavelength apart ona common vertical mast and are both pointed toward the signal source, any TV signals traveling horizontally and arriving from any direction will be intercepted simultaneously by both antennas. And those signals received on axis from the direction in which the antenna is pointed (figure 2B. page 2) will be the strongest.

Vertical Stacking, Cont'd.

Because the antennas are identical, the generated signal voltages arriving at the output terminals shared by the antennas will be in phase, causing them to add directly. Theoretically, there should be a 3 dB increase (double) in signal power over that of a single antenna, but because of losses in the coupler and cable, the actual gain increase will be somewhat less than 3 dB.

An important point to remember is that regardless of the azimuth angle between the antenna orientation and the signal source, the arriving signal will strike any given identical points on the two antennas simultaneously. If the signal is arriving from a source *above* or *below* the horizontal plane of the antenna, this is no longer true. For example, if the wavefront is from a source below the plane of the antenna (figure 2A), the signal will arrive first at the lower antenna and the signal voltage from the top antenna will lag the signal from the lower antenna. The signal voltages at the antenna output terminals will no longer be in phase, and partial cancellation will take place. The opposite is true if the signal arrives from above (figure 2C).

The angle of arrival and the resultant difference in arrival time causes a phase difference which reduces the magnitude of the combined voltages. You should begin to see now why two vertically stacked, identical antennas have a more restricted "vision" to signals arriving from a point above or below the horizontal plane than does a single antenna.

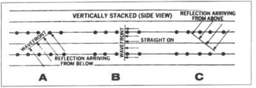


Figure 2: Side views of vertically stacked Yagi-type antennas showing relationship of antenna elements and arriving signals. (A) Signal reflected from below. (B) Signal received straight from source. (C) Signal reflected from above.

Figure 4

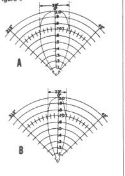


Figure 4: Polar patterns showing the effect of the horizontal stacked antennas in figure 3. (A) Pattern for a single CA-0000. (B) Narrower pattern produced by horizontally stacking two CA-0000 antennas one wavelength apart.

Figure 5

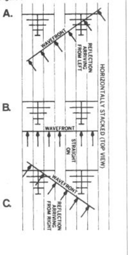


Figure 5: Top views of horizontally stacked Chromstar antennas showing relationships of antenna elements and arriving signals. (A) Signal arriving from left side. (B) Signal received straight from source. (C) Signal arriving from right side.

Horizontal Stacking

Stacking two identical antennas side by side in a horizontal plane significantly narrows the *horizontal* beamwidth angle (figure 4). This antenna combination, like a horse wearing blinders, "sees" fewer interfering signals arriving from the sides while its vision vertically is virtually unaffected. in the process, gain increases approximately 2.5 dB over that of a single antenna.

If two identical antennas are arranged side by side in a horizontal plane and the signal wavefront arrives directly from the front (figure 5B), each antenna "sees" the same wave or field at the same time. If the wavefront arrives from a source above or below, the same is still true, except that the individual antennas are not operating as efficiently. However, if the wavefront arrives from one side or the other (figure 5A and C), the antenna on the side the signal is coming to will "feel" the signal first, causing the voltages induce in each antenna to be out of phase. This causes partial cancellation of the antenna voltages when they are combined.

The vertical "vision" of a horizontal stack is comparable to that of a single antenna, but its side-to-side "vision" is more restricted.

Quad Stacks

Stacking four identical antennas, two vertically and two horizontally in a rectangular or diamond pattern, restricts the vision of this combination is all directions off the axis. Called a quad stack, it "sees" as though it were looking through a tube pointed in the direction of the transmitting antenna. Gain increases approximately 4 to 5 dB over that of a single antenna.

Techniques for stacking antennas

Before putting up an antenna array, check these basic considerations that apply to dual and quad stacking.

1. Stack only identical antennas.
2. Maintain approximately one wavelength spacing (at lowest channel frequency) between antennas.
3. Cut phasing lines or connecting cables to *equal* lengths, ±1/8".
4. Length and phase of twinlead interconnecting harnesses is critical.
5. Horizontal supports should be nonmetallic.
6. Avoid running interconnecting cables horizontally.

Vertical stacking is easier than horizontal stacking simply because vertical stacks mount on the same mast and spacing is easily adjusted.

Horizontally stacked antennas also must be spaced so booms are separated by a distance equal to more than one-half wavelength of the lowest channel frequency. This spacing is needed to prevent the tips of the longest reflector elements from touching. Horizontal supports must be *nonmetallic* — cypress, redwood or treated wood 2" x 4"s are commonly used.

Spacing

For optimum performance, stacked antennas must be properly spaced. If you do not space vertically and horizontally stacked antennas more than one-half wavelength apart, they will adversely "load" each other. Loading is caused by the elements of one antenna reradiating some of their received energy into the element of the other antenna, with consequent reinforcement and cancelation of fields and voltages. **Optimum and minimum spacing is 0.94 and 0.60** wavelength, respectively, at the lowest frequency received. Spacing exceeding one wavelength reduces the performance of the stack. (See Winegard's Spacing & Cable Lengths Chart.)

In a horizontal stack with elements tip-to-tip and the longest element the minimum practical spacing will be some distance over .6 wavelength, to prevent the longest element of one antenna from touching the tip of the corresponding element of the other antenna. Recommended spacing is 0.94 wavelength between booms at the lowest channel involved.

SPACING & CABLE LENGTHS

Channel	Vertical Spacing	Coax Length
2	145"	85.0"
3	130'	76.5"
4	120"	69.5"
5	105"	60.5"
6	100"	56.0"
7	48"	52.0"
8	46"	51.0"
9	44.5"	49.5"
10	43.5"	48.0"
11	42.25"	46.5"
12	41"	45.0"
13	40"	43.5"

Because of restrictions on space (usually height), there will be times when it is not practical to space antennas a full wavelength apart. But it should never be less than .6 wavelength. At less than .6 wavelength, performance deteriorates and advantages of stacked antennas are lost.

All parts of the antenna supporting structure should be made of wood or plastic. Horizontal metallic supporters act like antenna elements, and can cause unusual voltage/frequency effects from the antenna array. If using wooden supports subject to weather, use redwood or treated wood.

Interconnections

Connecting the antennas properly is as important as spacing and orienting them. Getting the individual voltages from each antenna to the point where they are combined without: 1) Combining out of phase, 2) Adding extraneous signals and noise through improper positioning, dimensioning and coupling of antennas, harness and/or connecting cables.

Stacking Techniques, Cont'd.

Antennas may be coupled by a phasing harness made from balanced transmission line (figures 6 and 7) or may be coupled with a hybrid antenna coupler (figures 8, 9, 10, p.4). Antenna couplers are simpler to hook up and are less critical and more durable than phasing harnesses. Harnesses must be cut to the precise length for a single channel frequency, kept straight and untwisted and, for horizontal stacking, must be installed and maintained at a 45° angle to the horizontal. The harness connections at the antenna and the combining point must be phased properly or the performance will be less than that from a single antenna. Along the length of any transmission line there will be voltage maximums and minimums. If the lines are to be interconnected, cut and connect them at points at which the voltages are maximum, or at odd multiples of a quarter wavelength. If the transmission lines are of different lengths, connect them at a point where their signals are in phase (multiples of a whole wavelength, longer or shorter) so the voltages will add.

Because wavelength changes with frequency, wiring harnesses are only practical for single-channel antennas. Multiple-band and wide-band antennas should always be connected with *broadband hybrid couplers*.

Antenna couplers simplify the interconnection of stacked antennas with 75 ohm coaxial cable, as shown in figure 10. Because of cable loss, cables should be kept as short as possible and of equal lengths. They can be taped to the metal boom or mast. But because cable is a metallic conductor, horizontal lengths parallel to antenna elements should be avoided; the cable shield might act as an antenna element, reradiating energy into the antenna and causing cancellation and ghosts.

Winegard offers two different series for stacking applications: the SD signal doubler and the CC multiset couplers. CC multiset couplers, although designed and sold principally

Figure 6

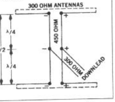


Figure 6: Harness arrangement for vertical stacking. Using a phasing harness to couple 300 ohm stacked antennas eliminates a coupler and avoids losses but can only be optimized for one channel. A harness is also susceptible to noise and is more time consuming to install. Phasing harnesses, made from balanced transmission line, must be precisely dimensioned, properly phased and carefully positioned to achieve satisfactory performance. Vertically stacked single channel 300 ohm antennas are connected in parallel using two quarter-wave lengths or 450 ohm transmission line. Phasing polarities must be strictly observed. In absence of polarity marking on antenna, consider corresponding right and left terminals on identical antennas as same polarity.

Figure 7

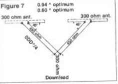


Figure 7: Harness arrangement for horizontal stacking. Two horizontally stacked, 300 ohm single-channel antennas require two equal lengths of 450 ohm balanced transmission line cut to an odd multiple of a quarter wavelength at the center frequency of the channel to be received and positioned at 45 ° to the horizontal. Phasing polarity must be strictly obseved. To connect a phasing harness, a quad stack (2 x 2) is seen as two separate vertical stacks, each preconnected and arranged in a horizontal stacked pattern. Connect the output of each vetical stack as you would each output of identical antennas in a horizontal stacked arrangement.

for coupling two TV sets to a single antenna downlead, also function well as antenna couplers.

In figure 8, SD signal doublers combine signals from any two identical 300 ohm antennas and provide either a balanced 300 ohm output (SD-3300) or a coaxial 75 ohm output (SD-3700).

Because SDs have only 300 ohm inputs, they are not recommended as highly for horizontal stacking as the CC-7870 which have 75 ohm inputs.

When connecting stacked antennas, correct phasing must be achieved or a null signal (no picture) will be produced at the coupler. If a null is observed, put a half twist in one of the 300 ohm lines to reverse the phase at the coupler terminals.

The CC-7870 channel multiset coupler (figures 9 and 10) is preferred over SDs for coupling identical, stacked antennas. When used as an antenna coupler, the individual antennas are coupled into the "TV set" (output) terminals of the CC and the output is taken from the "antenna downlead" (input) terminal. The device simply separates or combines signals. It doesn't know its input from its output and is only concerned with the *impedance* of the devices connected to its terminals.

Because 75 ohm coax cable is recommended for interconnecting stacked antennas and for downlead, coupler choices are CC-7870 two set coupler (for dual stacks) and a 75 ohm four-splitter in a weatherproof housing (for quad stacks).

Cautions to be observed when coupling stacked antennas include cutting the coaxial interconnecting cables into equal lengths, observing the correct phase, and installing cables away from antenna elements.

If 300 ohm antennas are used, impedance matching transformers such as TV-2900 (figure 10) are recommended to adapt the antenna output to the 75 ohm coax cable.

When using this or some other matching transformer, you must have correct *phasing* on the *300 ohm* side. You can easily measure for continuity between the threaded (shield) portion of the coaxial connector and one conductor on the 300 ohm side. The conductor that is determined should always be connected to a corresponding right or left screw terminal on each of the identical antennas for in-phase connections, or reversed for out-of-phase connections.

Figure 8

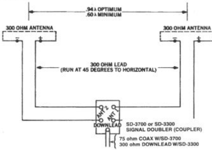


Figure 8: Method of using SD signal doublers to couple horizontally stacked antennas.

Figure 9

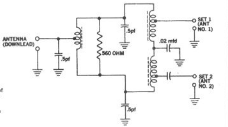


Figure 9: Photo and schematic diagram of Winegard CC-7870. This two-set coupler is designed for connecting two televisions to single downlead. It can also be used to combine the outputs of two stacked antennas.

Figure 10

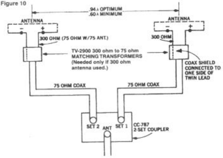


Figure 10: Method of using CC-7870 two-set coupler to combine the outputs of two horizontally stacked antennas. Coupling stacked antennas with a hybrid coupler and 75 ohm coax cable simplifies installation. Coaxial cable routed along the boom and metal supports causes no adverse effects. Phasing doesn't need to be considered except to make sure the coax shield is directly connected through the matching transformer to the corresponding antenna terminals. A simple ohm meter check on the matching transformer will show which side of the 300 ohm output lead is directly connected to the coax shield. Connecting anennas to a coupler using 300 ohm transmission line — an alternate method — does require careful attnetion to phasing.

Beyond dual or quad stacking...

Not much improvement in eliminating ghosting or man-made noise is gained by stacking more than two antennas horizontally or vertically. If more than two in either direction is indicated, consult with an experienced antenna installer or engineer.

There are techniques other than conventional stacking that can reduce TVI. Stagger stacking, tri-stacking and phasing harnesses are useful, but these require expertise beyond a non-professional level.

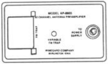
Winegard Company has many *area specials* — antennas for specific areas designed to overcome particular problems and eliminate the use of a rotor. If they do not have an area special for your locale, the Winegard dealer/distributor in the area can have Winegard "design" a special antenna array to solve reception problems for you.

Preamplifiers...

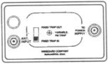
Preamps only amplify the net result of the stacked antenna array. **They will not extend the range of the antennas.** Figure 11 shows model numbers and specifications for most Winegard preamplifiers.

MODEL	INPUT			OUTPUT	AVERAGE GAIN		AVERAGE NOISE FIG.		MAXIMUM TOTAL INPUT# (MICROVOLTS)	
	VHF	UHF	82 CH.		VHF	UHF	VHF	UHF	VHF	UHF
AP-2870	75	75		75	17 dB	19 dB	2.9 dB	2.9 dB	110,000 µV	93,000 µv
AP-2880	75	75		75	29 dB	19 dB	2.9 dB	2.9 dB	29,000 µV	93,000 µV
AP-3700	75 or		75	75	17 dB	By-Passed	2.6 dB	N/A	110,000 µV	N/A
AP-3800	75 or		75	75	29 dB	By-Passed	2.9 dB	N/A	29,000 µV	N/A
AP-4700		75 or	75	75	By-Passed	19dB	NA	2.9dB	NA	93,000 µV
AP-4800		75 or	75	75	By-Passed	28 dB	N/A	2.7 dB	N/A	30,000µV
AP-8275			75	75	29 dB	28 dB	2.9 dB	2.8 dB	29,000 µV	30,000 µV
AP-8283			300	75	29 dB	28 dB	2.9 dB	2.8 dB	29,000 µV	30,000 µV
AP-8700			75	75	17 dB	19 dB	2.8 dB	2.8 dB	110,000 µV	93,000 µV
AP-8703			300	75	17 dB	19 dB	3.9 dB	3.9 dB	110,000 µV	93,000 µV
AP-8733	300	300		75	17 dB	19 dB	3.9 dB	3.9 dB	110,000 µV	93,000 µV
AP-8780			75	75	17 dB	28 dB	2.9 dB	2.7 dB	110,000 µV	30,000 µV
AP-8783			300	75	17 dB	28 dB	3.9 dB	3.9 dB	110,000 µV	30,000 µV
AP-8800			75	75	29 dB	19 dB	2.7 dB	2.8 dB	29,000 µV	93,000 µV
AP-8803			300	75	29 dB	19 dB	3.9 dB	3.9 dB	29,000 µV	93,000 µV
AP-8833	300	300		75	29 dB	19 dB	3.9 dB	3.9 dB	29,000 µV	93,000 µV

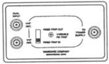
Output capability is stated for 7 VHF and 5 UHF channels at -46 dB cross modulation.



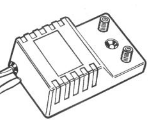
300 ohm



75 ohm



Dual Input



Power Supply

Vertical Stacking Winegard Chromstar® FM Antennas

Stacking two CA-6065 FM antennas is an excellent way to increase gain, improve directivity and increase capture area.

When **gain** is an important factor, stacking FM antennas can provide enough boost in signal to establish a much better signal-to-noise ratio in the first amplifier.

Good **directivity** in an FM antenna can eliminate many reception problems such as airplane flutter, reflected signals and noise pickup from ground level sources. Vertically stacking two FM antennas can also narrowvertical beam width directivity up to 30%.

By increasing **capture** area of the CA-6065, fading problems of very weak signals can be eliminated. There can be up to 40% improvement (3 dB extra gain) when using more than one antenna.

For vertically stacking two Chromstar FM antennas on a tower, the following procedure allows the array to be assembled in steps as the mast is raised up out of the tower top.

Equipment required:

1. Two Chromstar FM antennas.
2. One CC-7870 coupler.
3. Two (2) pieces coax, 52" long.
4. Masting 10' long.
5. Mount
6. Coax download.

Assembly instructions:

1. Unfold both antennas.
2. Install terminal board/housing.
3. Insert coax up through boot and install F-connector on coax, then attach coax to cartridge housing. Slide boot onto boot collar.
4. Mount upper antenna on mast.
5. Mount CC-7870 coupler approximately 36" below upper antenna.
6. Connect coax cable from upper antenna to "set 1" jack of coupler and tape cable to mast.
7. Connect coax cable from housing bottom for lower antenna to "set 2" jack on coupler and tape to the mast.

NOTE 1: If preamplifier is not required, the downlead should be connected to the "antenna" jack on coupler at this point.
NOTE 2: If a preamp is required, a third length of coax cable must be attached to "antenna" jack on coupler and taped to mast at lower antenna.

8. Mount lower antenna on mast approximately **72"** below upper antenna.
9. Secure coax to mast.

This completes assembly if preamplifier is not used. **Go to step 10 if preamp is used.**

10. Mount preamplifier housing below bottom antenna.
11. Slide boot over loose end of coax cable and install connector. Attach to "antenna" jack of coupler.
12. Attach other end of coax to "input" on preamplifier.
13. Run coax downlead to "input" on power supply.
14. Hook up jumper tojack marked "To TV" and plug into power source.

Selecting preamplifier..

In metropolitan areas or where strong local TV signal is present, use **AP-3700** (FM trap out-position).

For medium to weak reception areas, or where no strong TV or FM stations are present (FM trap out position), **AP-3800**.