World's Longest Logi?

A NEW HIGH BAND ANTENNA THAT GIVES RHOMBICS A GOOD RUN FOR THEIR MONEY

End Fire/Broadside/Surface Wave???

Most cable people have a natural interest in antennas; it is, after all, the antenna which separates the cable receiving site from the home receiving site. As the previous report pointed out, when you are serving rural cable subscribers with as few as ten homes per mile you have to be extremely clever with your off-air receiving site to make the whole system financially feasible. And as pointed out previously, Arizona's Oliver Swan is clever.

The data supplied to CATJ by Oliver Swan is his own data. It does not all find verification in antenna reference manuals. We point this out because we anticipate receiving a number of letters from "antenna engineers" in the crowd who find one or more reasons to dispute some of Oliver Swan's statements, numbers or diagrams. Our position in this is very simple. Oliver Swan's antennas work. They have worked for more than 25 years now. Admittedly they have never previously received national (or world wide in our case) attention. That is no fault of Oliver Swan nor does it in any way tarnish the ability of his antennas to produce signals in areas where previously no signals existed at a useable level. Swan's antennas are in regular use in some very remote areas, providing television reception over paths as long as 385 miles. We know. . .we've been there and we've seen them work.

So we anticipate hearing from people who find some of Oliver's statements difficult to equate to their own experiences. We'll gladly print any such comments in future issues of CATJ.

The end-fire (yagi) antenna has been used in television reception for as long as there has been television, and it has good directivity and bandwidth for single channels in the high band (7-13) region. When a yagi is used for broad banded reception, the maximum (gain) directivity is limited to approximately -3 dB at 5% of the center frequency. In other words, a yagi antenna cut for 61 MHz (channel 3 visual) will have gain plus or minus 3 dB of the maximum gain at a frequency 5% below 61 MHz (57.95 MHz) and at a frequency 5% above 61 MHz (64.05 MHz). Keep in mind that this "3 dB point" means gain has fallen off by 3 dB by this point(s) in the spectrum. **See diagram 'A' here.**

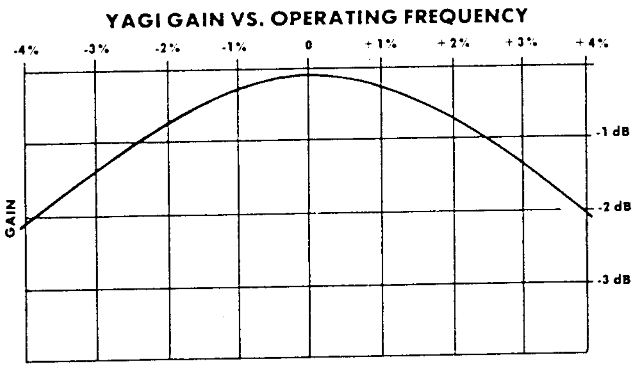


DIAGRAM A

Thus the yagi will not work very well at low band frequencies, although it is useable within the 3 dB criteria for high band frequencies (5% below 181 MHz [channel 8] is 171.95 MHz while 5% above 181 MHz is 190.05 MHz; well within the 180-186 MHz spread of channel 8).

The yagi has another inherent problem and that is impedance. Multiple element yagi antennas are just naturally low feed impedance devices (10-20 ohms is not uncommon). There are several ways to get the impedance stepped up but most of these techniques involve some form of transformer system to arrive at (our) desired 75 ohm impedance. Other choices for changing the feed impedance are:

1. Adjust the director by varying the length, size (diameter) and/or spacing;
2. Used a folded or multiple element dipole antenna;
3. Adjust the reflector by varying the length, size (diameter) and/or spacing.

Virtually any modification to the yagi array will bring about a decrease in the (gain) directivity. In other words, to attain a match to the feedline, some of the desirable directivity (gain) must be sacrificed.

What is it about the yagi which makes it a frequency-selective antenna? The directors, it turns out, are relatively broadband in nature **(see** diagram 'B'). The driven element is a relatively "hi-Q" circuit however, and unless modified, it wants to work on one frequency best. When there is a mismatch between the "fed element" and the feedline, the mis-match in impedance between the two creates loss **(see diagram 'C')**. It might be worthwhile to ask at this point why the feed system is inadequate.

% OF OPERATING FREQUENCY

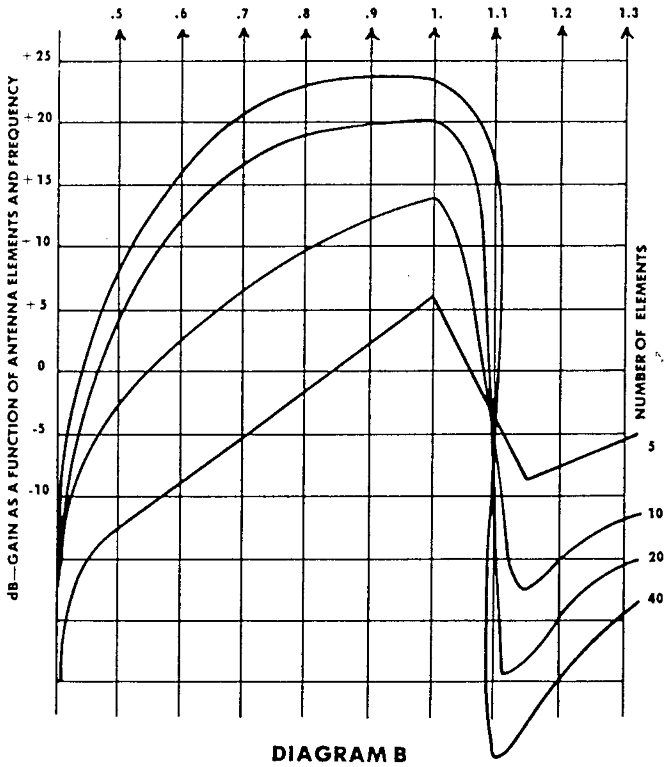


DIAGRAM B

YAGI MATCH VS. OPERATING FREQUENCY

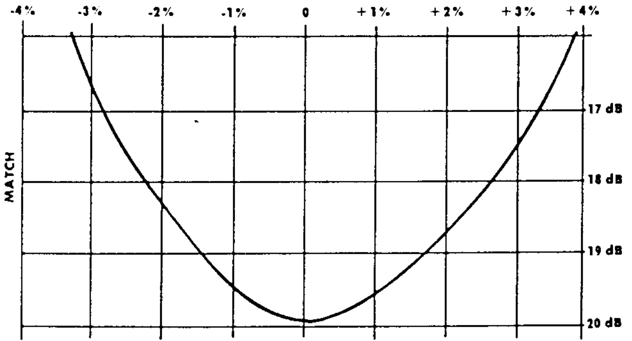


DIAGRAM C

Diagram 'D' illustrates that a straight dipole (fed element) radiates like a doughnut, around its length, equally well (or poorly) in all directions. The director(s) and reflector(s) however are in a single plane, and they therefore cannot capture and re-radiate energy in more than in that single plane. That contributes to the lack of a broadbanded nature between the feed element (dipole) and the balance of the antenna array. The fed element in effect becomes a form of parasitic "bandpass filter" hanging in space and "tuned" by the elements around it to a "hi-Q" condition. It might be useful, if you are into bandpass filters, to picture the yagi or end fire array as an "interdigital bandpass filter" suspended in space.

RADIATION PATTERN OF DIPOLE

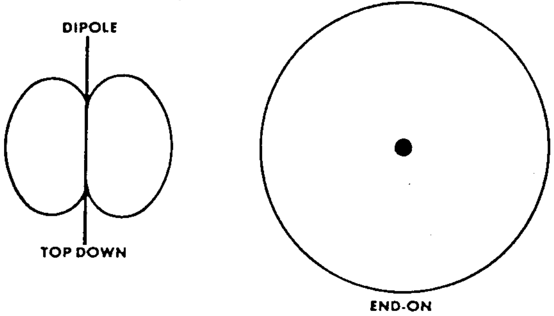


DIAGRAM D

One way around this problem is to modify the feed system of the yagi or end fire array **(see diagrams 'E', 'E-1' and 'E-2')** four separate ways, as follows:

(1) Modify the distance to the directors (director loading affects fed element resistance or impedance);
(2) Modify the feed resistance (impedance) of the fed portion of the antenna, by combining in series-parallel separate fed elements;
(3) Modify the directivity of the feed system (by combining fed or active elements some of the circular properties of a single fed element are warped into a more linear format);
(4) Modify the bandwidth of the fed-element segment by broad banding the feed system with series-parallel connected sections operating on slightly different frequencies **(diagram 'E-1')**.

COMBINING DRIVEN ELEMENTS OF DIFFERENT RESONANT FREQUENCIES

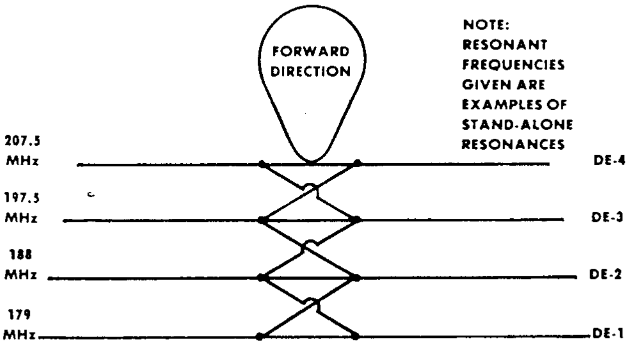
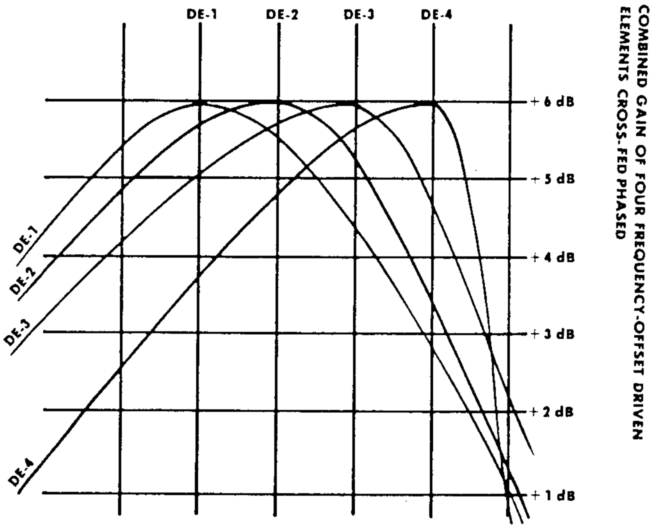


DIAGRAM E

With this approach to fed elements on an end-fire (yagi) array we have re-structured our bandwidth of the antenna with optimum (gain) directivity plus we have arrived at a 75 ohm (balanced) feed system without transformers.

In fairness, there is another solution to the

EFFECTIVE GAIN [OVER SINGLE DIPOLE] OF FOUR DRIVEN ELEMENTS



EACH DRIVEN ELEMENT SEES RESONANCE AND MAXIMUM GAIN AT A DIFFERENT FREQUENCY. THE FOUR FREQUENCIES ARE COMBINED BY CROSS—FEEDING ELEMENTS OF DIFFERENT LENGTHS. SEE DIAGRAM E.

DIAGRAM E-1

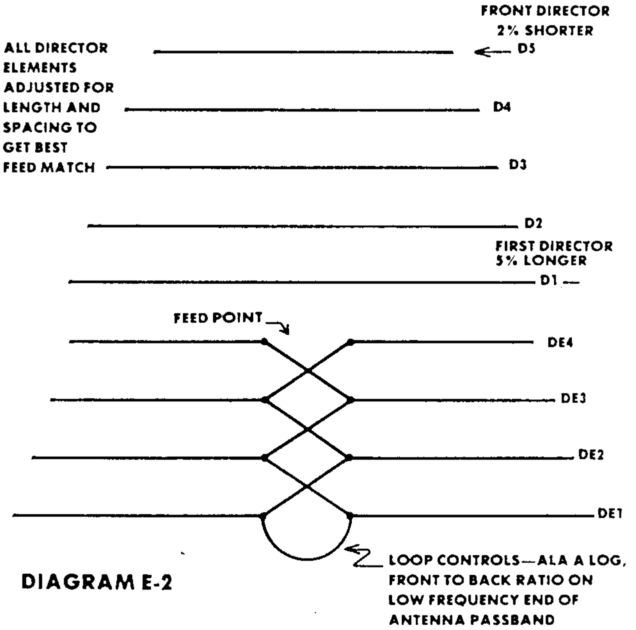
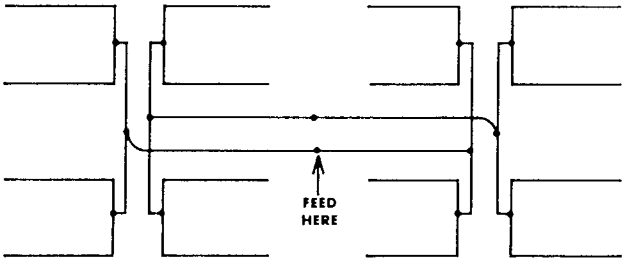


DIAGRAM E-2

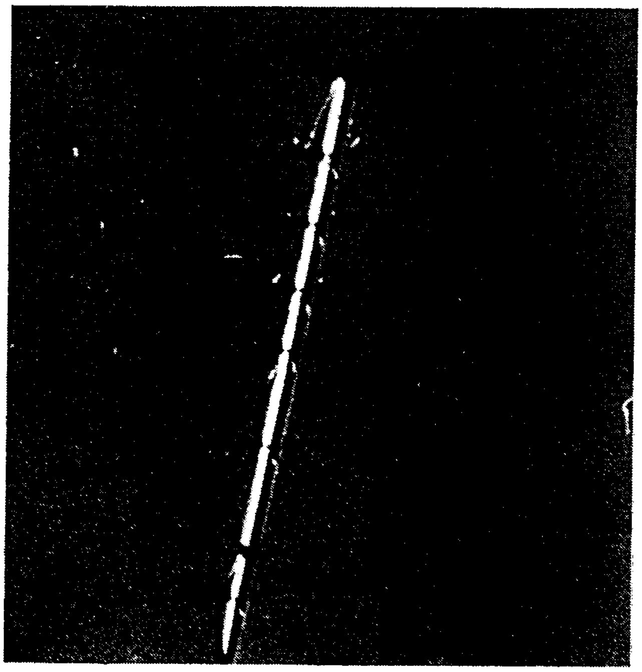
same problem and that is to employ broadside or colinear elements as shown in **diagram 'F'**. The primary problem with a colinear array is its size and the losses in the matching sections; and the matching sections will be frequency selective. But the broadside or colinear type of array is informative none the less because it illustrates how multiple yagi or end fire arrays, constructed so as to form a multiple antenna array, can be combined so that the gain of the entire array is the gain of the sum of the various component antennas. One approach to combining antennas, not often practiced in CATV headends, is to throw away the combiners typically utilized to combine arrays and to substitute matching sections of coaxial cable **(diagrams 'G' and 'G-1')**. It works out **(diagram 'G')** that if you utilize commonly available 50 and 75 ohm cable, as shown in **diagrams 'G'** and **'G-1'** to create matching sections and balanced to unbalanced transformers, you can eliminate any external ferrite or other matching and combining equipment. It is still a frequency selective matching system, but it is lower in cost than most other techniques, and the reliability is as good as the reliability of the cable matching sections themselves and your own construction practices. The 180 degree phase shift matching section is a very efficient system for combining on a single channel; the loss of the matching section is the loss of the cable and fittings only. The antenna-combiner system **(diagrams 'G' and 'G-2')** starts to become frequency selective beyond the fourstack array point however, even within a single (low band) channel.

BROADSIDE (COLINEAR) ARRAY



THIS TYPE OF ARRAY (DIPOLES ONLY SHOWN) HAS A BROADER FREQUENCY RESPONSE BUT MATCHING SECIONS ARE FREQUENCY SELECTIVE

DIAGRAM F



FEED SECTION OF SWAN 'LOGI'. Top element is reflector, next four are driven elements, followed by close-spaced director and then equally spaced directors (towards bottom). Downline tapes along boom.

COAXIAL LINE SECTION ANTENNA COMBINING

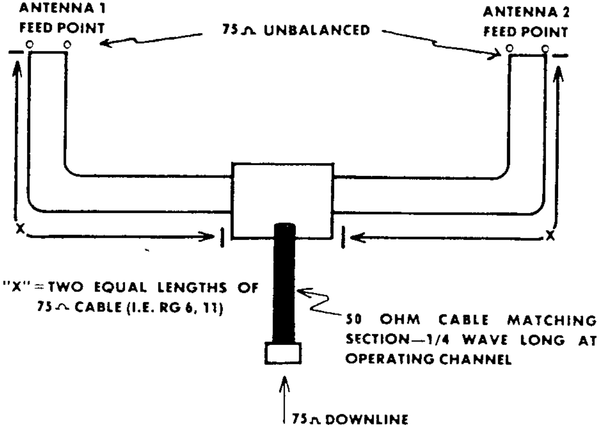


DIAGRAM G

75Ω BALANCED TO 75Ω UNBALANCED SECTION

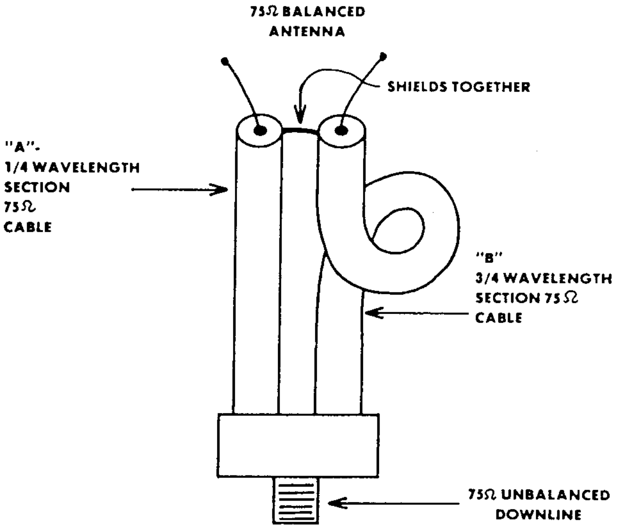


DIAGRAM G-1

COMBINING TWO 75Ω BALANCED ARRAYS WITH [G-1/G-2] COAXIAL LINE SECTIONS

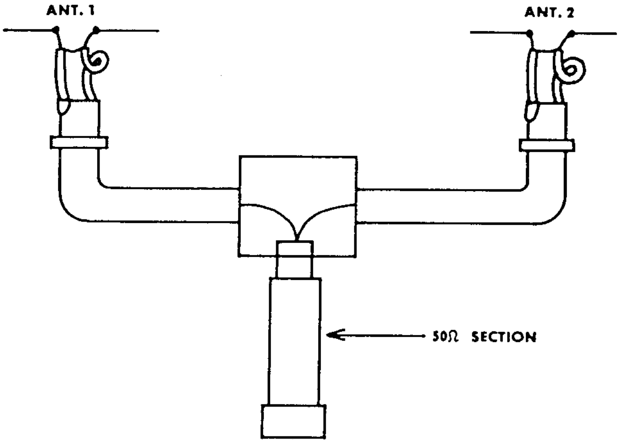
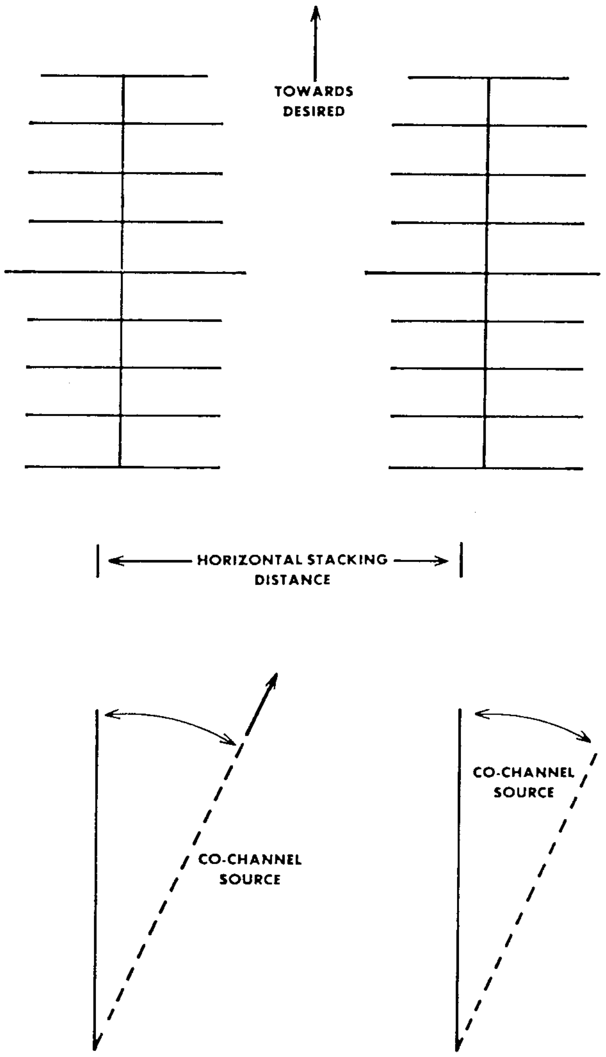


DIAGRAM G-2

USEFUL DIMENSIONS FOR DIAGRAMS 'G' AND 'G-1'

The following cable-dimensions will be useful in constructing 1/4 and 3/4 wavelength sections of cable per diagrams 'G' and 'G-1'.

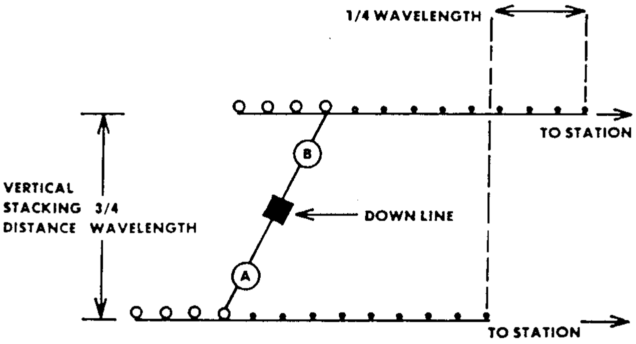
Channel	Frequency	1/4 wave in 75 ohm RG-6	3/4 wave in 75 ohm RG-6	1/4 wave in 50 ohm RG-8 (foam)
2	54- 60 MHz	42 "	125.75"	37.2"
3	60- 66 MHz	37.9"	113.9 "	33.6"
4	66- 72 MHz	34.7"	104.0 "	31.2"
5	76- 82 MHz	30.1"	90.4 "	26.9"
6	82- 88 MHz	28.1"	84.5 "	25.0"
FM	88-108 MHz			21.0"
7	174-180 MHz	13.5"	40.5 "	12.0"
8	180-186 MHz	13.1"	39.3 "	11.5"
9	186-192 MHz	12.7"	38.1 "	11.0"
10	192-198 MHz	12.3"	36.9 "	10.5"
11	198-204 MHz	12.2"	36.7 "	10.0"
12	204-210 MHz	11.9"	35.7 "	9.5"
13	210-216 MHz	11.2"	33.6 "	9.0"



BY SELECTING HORIZONTAL STACKING DISTANCE, OFF-HEADING CO-CHANNEL SOURCES APPEAR AT COMBINED ANTENNA OUTPUTS 180° OUT OF PHASE AND CANCEL (SEE CATJ FOR JUNE 1974; PAGES 7-16).

DIAGRAM H

STAGGER STACKING TO IMPROVE CO-CHANNEL REJECTION TO REAR



VERTICAL STACKING OF 3/4 WAVELENGTH IS PRACTICAL MINIMUM FOR EFFECTIVE GAIN [CAN BE INCREASED TO 1 WAVELENGTH FOR ADDITIONAL GAIN OF 1/2 dB]. ONE ANTENNA LEADS OTHER BY 1/4 WAVELENGTH IN FREE SPACE. SEE TABLE I-1 FOR LENGTHS OF COMBINING CABLES A AND B .

DIAGRAM I

Some Figures

If your incoming wave front is uniformly distributed (i.e. it is arriving at the front of a multiple-antenna array at the same level and phase over the full array) the gain to be achieved with two stacks of antennas utilizing the coaxial combining and matching techniques outlined here is on the order of 2.8 dB over a single stack array. A four stack array will net approximately 5.5 dB gain over a single array, under the same incoming wave front conditions. When there are uneven wave fronts arriving at the multiple-antenna array, the net gain of additional stacks will often be much greater than the numbers given if you were to dis-connect an antenna that happened to be up high on signal level at that instant, and then compared it to an antenna that was by chance low in level at that point. This is the stuff that diversity antenna arrays are made of.

The two stack and the four stack array has more useful functions than gain alone of course. If you happen to have a co-channel or adjacent channel signal source problem, careful selection of the horizontal stacking distance **(see diagram 'H' and CATJ for June 1974, page 7)** can create very effective 20-40 dB "nulls" in the array pattern(s) towards the non-desired station or channels. The angular degrees between the two incoming signals determines the percentage of wavelength the antennas must be separated (again, see CATJ for June 1974, page 7) and this translates to real world stacking distances as a function of the operating frequency **(see diagram 'I' and table 'I')**.

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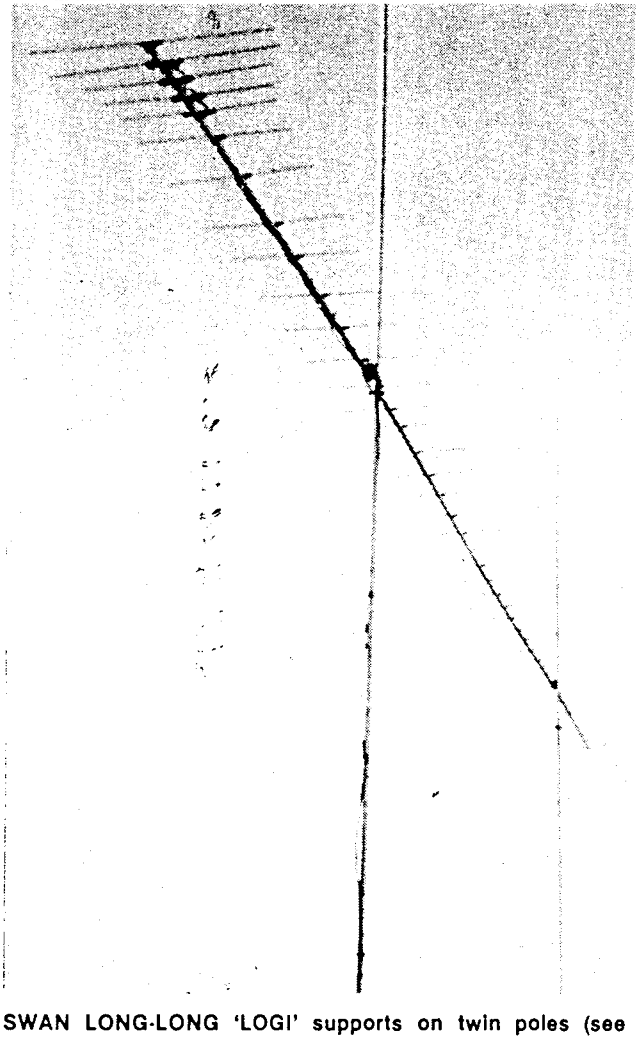
USEFUL DIMENSIONS FOR DIAGRAM 'I'

Diagram 'I' shows one method of "stagger-stacking" identical antennas to reduce co-channel pick-up from the rear of the antenna system. By placing one of the two identical antennas (top in this case) **physically 1/4th wavelength in front of the second antenna you create a 90 degree phase imbalance between the two for forward and rear direction signals** (i.e. the two antennas do not intercept the wavefront at the same point "in time" and there is phase imbalance). **By making the stacking/phasing lines further imbalanced the received signal must travel an extra 1/2 wavelength to the combining point for rear signals than it does for forward signals. This creates 180 degree phase imbalance for rear-of-array signals, but 0 degree phase imbalance for forward of array signals. The result is phase cancellation of rear-of-array signals. Dimensions here are for 1/4 and 3/4 wavelengths in free space** (the antenna leading dimension and the vertical stacking dimension respectively) **and for the cable lengths (A) and (B) in diagram 'I'.**

Channel	3/4 Wavelength in space	1/4 Wavelength in space	Line A Length(*)	Line B Length(*)
2	153"	51"	Any length	+ 42"
3	139.5"	46.5"	Any length	+ 38.25"
4	127.5"	42.5"	Any length	+ 34.75"
5	111"	37.0"	Any length	+ 30.25"
6	103"	34.5"	Any length	+ 28.0"
7	49.85"	16.65"	Any length	+ 13.65"
8	48.75"	16.1"	Any length	+ 13.1"
9	46.5"	15.5"	Any length	+ 12.75"
10	45.35"	15.1"	Any length	+ 12.35"
11	43.85"	14.65"	Any length	+ 11.85"
12	42.5"	14.25"	Any length	+ 11.65"
13	41.65"	13.85"	Any length	+ 11.25"

*** - Coaxial combining lengths are for foam type combining cables. Both (A) and (B) cables are of such a length that the (B) cable is 1/4th wavelength (in cable) longer than the companion (A) cable. In other words, cut the two cables so they are of a length that (B) is the right hand column length longer than (A). The right hand column is 1/4th wavelength in foam cable for the operating channel.**



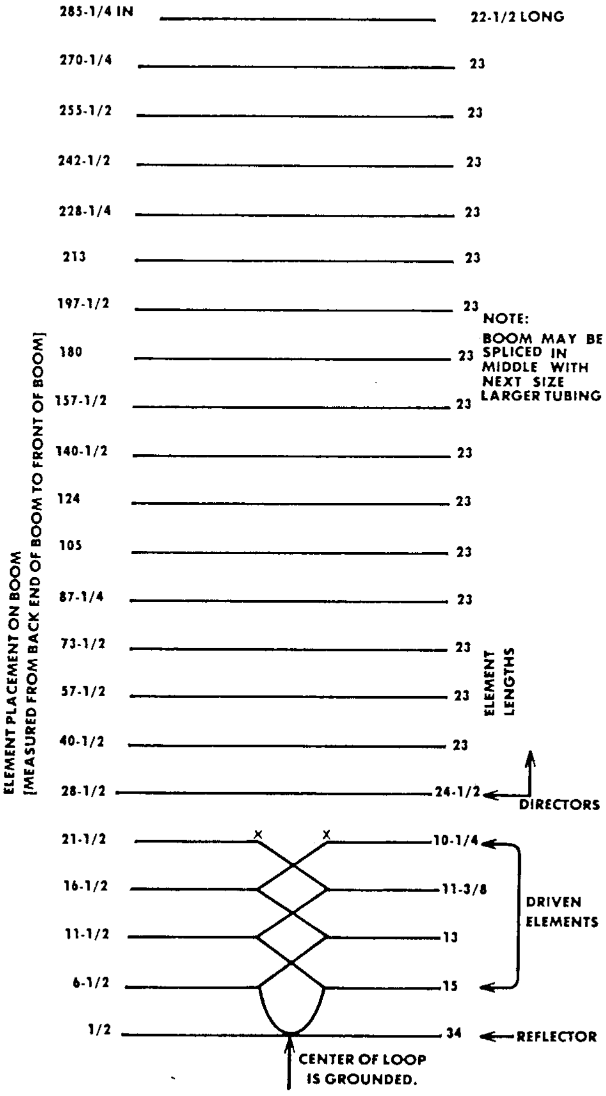
SWAN LONG-LONG 'LOGI' supports on twin poles (see diagrams L and M at end of report).

Surface Wave Antenna

When the yagi antenna first became popular in television reception in the early 1950's, there was a series of size expansions from the first elementary 3 element versions to some that eventually boasted 12-14 elements in line on the boom. But practical experience in the field showed that as the number of elements was increased, around a singular or even dual dipole feed system, the bandwidth of the antenna became worse and worse. Most people believed this band width limitation was the direct function of the directors being bandwidth limiting. That is not necessarily the case at all; the directors play a part, to be sure. But it was their impact upon the feed system which resulted in the antenna losing bandwidth rather than directors having a bandwidth problem themselves. The problem 'nipped long yagis' in the bud however and soon attention was diverted to other antenna forms and the yagi fell into apparent dis-favor because of its 'bandwidth problem'.

The approach we have utilized since the development in 1953 of the "Swan Feed" system has just about answered that problem for most conventional CATV uses of yagi antennas. The solution, we offer, is to modify the feed system as shown in diagram 'E' so that it "thinks" it is a broad banded feed system. Then the directors can be placed in front of the feed system without concern for what happens to the bandwidth; **for at least +/-12.5% of the operating frequency.** This results in an antenna system that can have directors added for as long in front of the feed system as the designer can measure improved (gain) directivity or performance. The point of diminished returns, we offer, is far beyond the 12 or 14 element antenna point. **See diagram J.**

22 ELEMENT SURFACE WAVE ANTENNA



CONNECT FEED LINE BALUN AT X
CH 7 THRU 13 10-1/2 WAVE LENGTH LONG

DIAGRAM J

There is, of course, a point of diminishing returns. For a high band array you begin to **approach** that point with an array of approximately 47.5 feet in length (**see diagram 'J-1'** for addition of 19 more directors on the "basic" array of 22 elements as shown in diagram 'J'). The point of diminishing returns is gradually reached as ohmic losses begin to add more rapidly than the additional (gain) directivity is added.

(NOTE: The dimensions given in diagrams 'J' and 'J-1' are suitable for the self-construction of an identical array to that shown here. Diagram 'J-2' shows how the boom material is spliced to add the front 19 directors to the rear 22 elements. Diagram 'J-3' illustrates how the driven elements are insulated from the boom [top] and "cross fed" [bottom]).

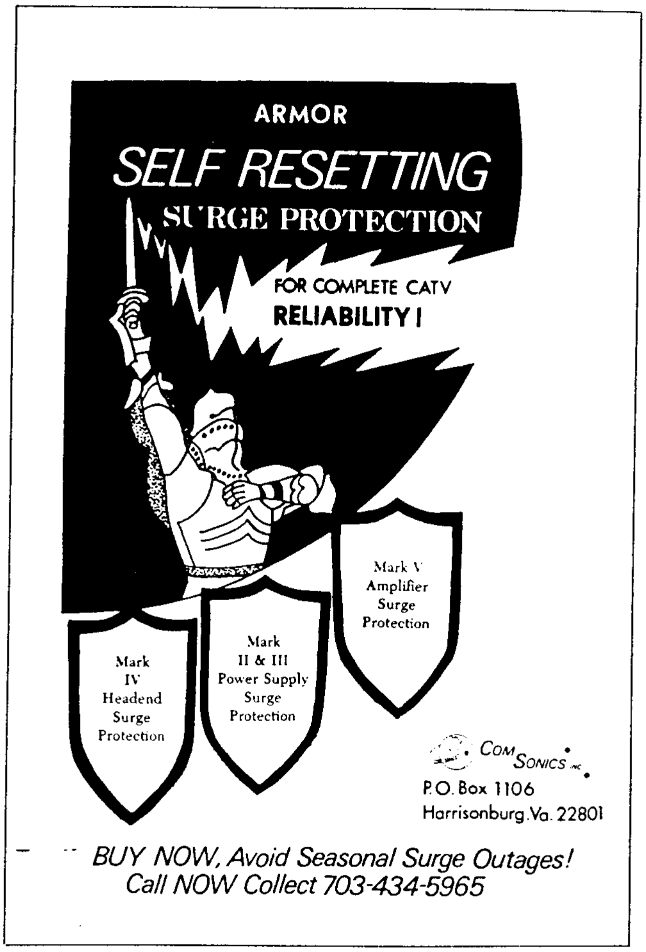
In case it has escaped you to this point, the only way an antenna "builds gain" is through increasing the directivity of the full array. And directivity comes by eliminating or reducing side and rear lobe responses and forcing the antenna to "see" only signals that are coming from wave fronts that enter the array from the forward direction (or over and along the directors which act as "guides" for the incoming wavefront). As the length of the array increases (i.e. directors are added) we have two things happening:

(1) The directivity or sharpness of the forward pattern improves (by becoming more and more narrow);

(2) And the gain of the array, correspondingly, increases.

This is shown in diagram 'K'.

In diagram 'K' we see that an antenna that is 8.5 half-wavelengths long (or the same as our basic 22 element array shown in diagram 'J') has a forward gain of 19.5 dB with a half power beamwidth of approximately 8 degrees. The full array, 47.5 feet long (**diagrams 'J' plus 'J-1'**) is nearly 17 wavelenths long, and it has a gain according to diagram 'K' of 21.5 dB and a half power beamwidth of approximately 6 degrees. The important thing to remember here is that we are looking at gain and half power beamwidths over **all** of high band or channels 7-13. We can do this because of the design of the feed system. Two such arrays will produce respectively 19.5



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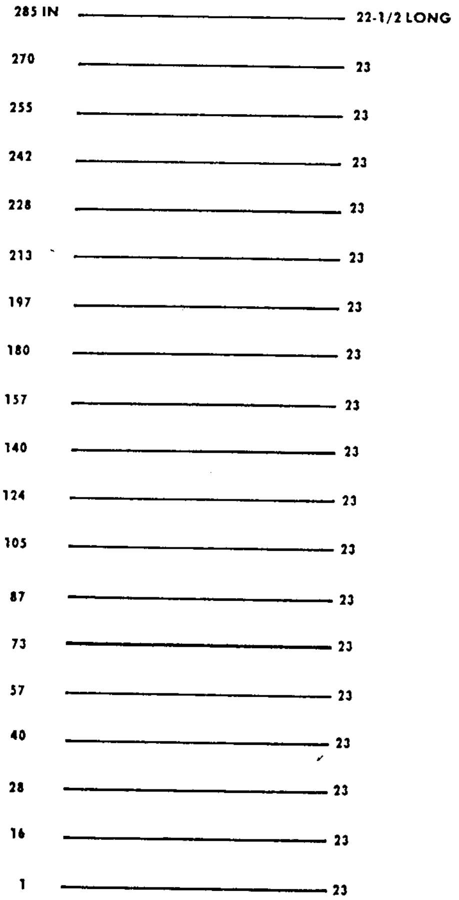
plus 2.8 dB or **22.3 dB of forward gain** (for the 22 element version) or 21.5 plus 2.8 dB or **24.3 dB of gain** for two of the 41 element versions. Stacking four of the 41 element arrays will produce 21.5 plus 5.5 dB or 27 dB of forward gain. This is right up there in the rhombic antenna class (**see CATJ for October 1976**)!

Just to set everything in perspective, this is the type of gain you would achieve if you stacked or phased say 200 dipole arrays. The problems associated with matching and phasing that many dipole arrays would of course be extra-ordinary. But of even greater importance, when you are working in a deep fringe area, the area where you find signal is often no more than 30 feet high by 30 feet wide. Since gain-addition only comes when all of the fed elements of a multiple stack array are receiving relatively coherent (i.e. in phase) incoming wavefront signal, it follows that to "build" large signal voltages in areas where signals are low, and spotty, you have to "squeeze" as much gain into the "hot area" (such as 30 feet by 30 feet) as possible. Antennas falling **outside** the area where there is consistent signal circumstances actually degrade the performance of the full array.

NOTE: BOOM MAY BE SPLICED IN CENTER AS NEEDED WITH NEXT SIZE LARGER TUBING



REPLACE THE 22-1/2 ELEMENT ON THE FRONT OF THE 22 ELEMENT SURFACE WAVE ANTENNA WITH A 23 IN. ELEMENT AND ADD THE ABOVE ARRAY TO THE FRONT END OF IT WITH 24 INCH SPLICE AS SHOWN IN DIAGRAM K-2.

DIAGRAM J-1

Installing The Big One

Start off with a test antenna of known (gain) directivity. Make measurements over the full area to determine (1) the width, (2) depth and most important the most productive heights (above ground) for the incoming wavefront. Repeat the tests when there are several different types of weather along the path from the

BOOM SPLICE/ADDITION OF 19 DIRECTORS TO 22 ELEMENT ARRAY

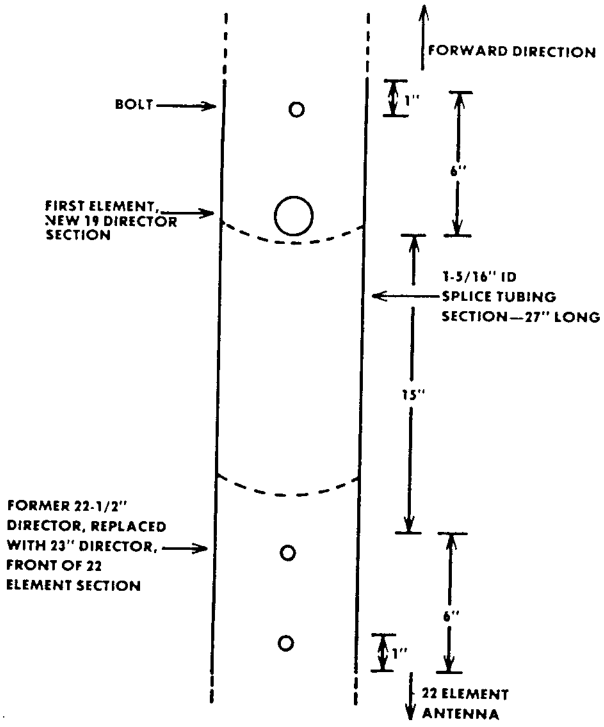


DIAGRAM J-2

DRIVEN ELEMENTS—SIDE VIEW

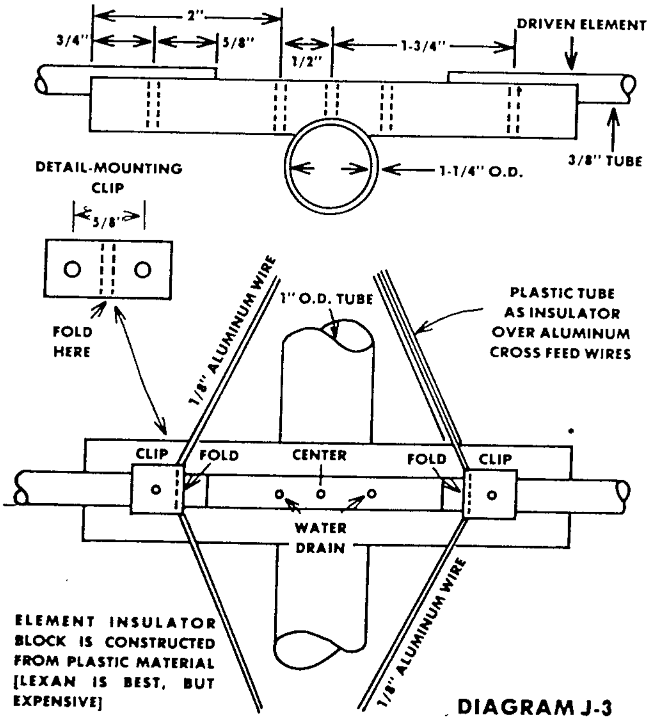


DIAGRAM J-3

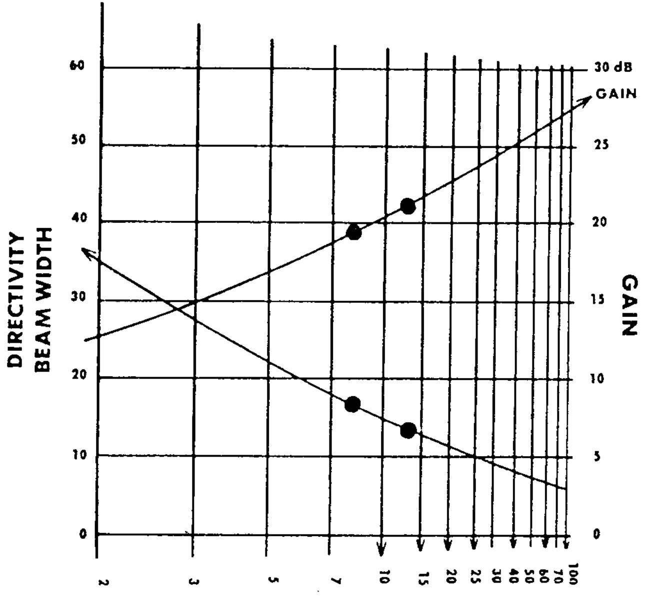
transmitter to your selected receiving site. Put stakes in the ground so you can return to the same exact spots and heights for later verifications of the signal levels. Repeat the tests at several different times of day.

The key is to put the antenna (whatever antenna) **where the signal is!**

(For the record, Swan says that with two of the long arrays stacked he can see an increase in background noise when the sun is directly in front of the array. That translates in a 4.5 MHz bandwidth to a fairly decent antenna gain figure and an unusually low background noise level from manmade and terrestrial sources.)

If the signal wavefront tends to move around abit, two (or more) antennas can be stacked in such a way that after your antenna site tests have narrowed down the area in which the signal moves around, you can place an antenna in both (or each) of the "hot spots" to allow the antennas to "track" (as in diversity) the wandering signal **(diagram 'L').**

SURFACE WAVE GAIN WITH SWAN FEED



LENGTH IN 1/2 WAVES
DIAGRAM K

Support

The best (and perhaps least expensive) support system for these long arrays will be a set of two or three metal telescopic poles. Swan utilizes a system similar to that shown in **diagram 'M'** on most of his Arizona and New Mexico installations. Because of the high forward directivity of the array it must be anchored so as to not move around from side to side (wind blowing the array will create a form of buffeting that will translate to signal fading as the array moves left and right of dead-on the incoming wavefront). The array needs to be grounded and Swan says that by installing 3 foot metal lightning rods at the **top** of the masts and running grounding wires down the masts to **driven ground rods** he has never had a lightning problem; nor has he ever lost a pre-amplifier.

The array has a "match" of from 18 to 28 dB typically and the gain is +/- 1 dB of the total over the full frequency range from channel 7 through 13. Within any single channel, sweep tests indicate the match is within +/- 1/4 dB and gain variation is virtually not measureable.

ANTENNA MOUNTING/POSITIONING

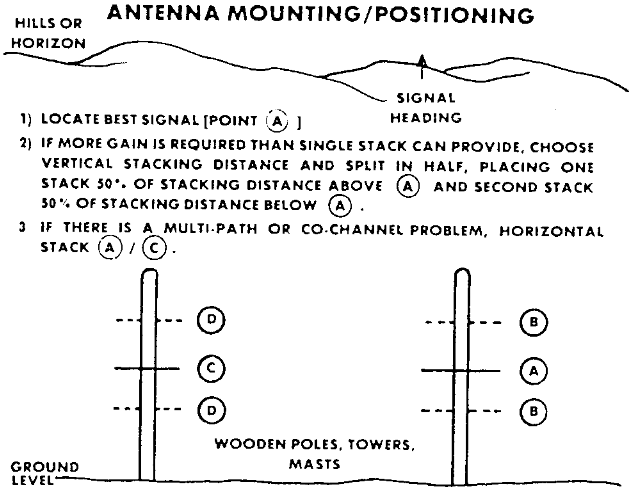
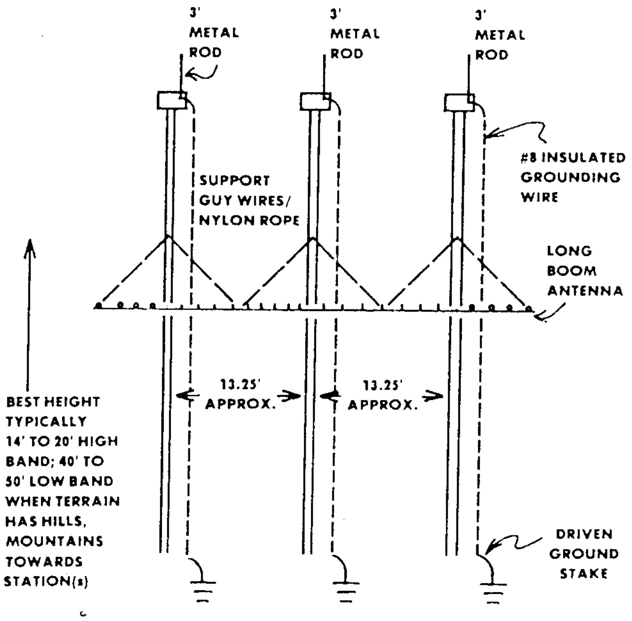


DIAGRAM L

HANGING UP A 40 FOOT BOOM HIGH BAND ANTENNA



OLIVER SWAN REPORTS "I HAVE NEVER LOST A PRE-AMP TO LIGHTNING USING THIS METHOD OF ANTENNA MOUNTING".

DIAGRAM M

FINDING OLIVER SWAN

Readers interested in pursuing the electronic packages or antennas discussed in CATJ this month will be able to locate Oliver Swan as follows:

Mr. Oliver W. Swan
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