See what
high-performance stations
do to achieve big-gun status
on 80/160 meters

secrets of successful
low band operation: part 1

I was curious . . . I would often hear stations on the low bands comfortably exchanging signal reports with rare DX contacts and wonder what type of antenna system they were using to achieve such good results. Therein was the beginning of a project that has provided more answers and technical enjoyment than I would ever have imagined possible.

Late last year a three-page survey was composed and sent to 113 of the "big gun" station operators and owners. After reading and digesting a two-inch thick sheaf of replies, many of my questions — as well as many unasked ones — have been answered. It is our pleasure to share this information with you. Much can be learned from the thousands of hours of experience in not only system design but also propagation observations made through the use of these outstanding systems.

A sincere note of thanks is due to the 47 individuals who took the time to fill out the lengthy survey form. Although a considerable amount of information was requested, some respondents not only entered their answers to questions but added more data as well. Responses were received from 21 countries from all continents. A special note of thanks goes to our overseas friends who, besides providing the data, responded in English, which is, for the most part, not their primary language. Responses were received from the following:*

CN2AQ	DJ0IA	DL0WU	EA8ADP	G2PU
G3WMZ	G4AMN	GW4OFQ	I5NPH	JA1FRE
JF1IST	K1MEM	K2FV	K3ZO	K5UR
KG7D	LA7ZO	N1ACH	N4AR	N4RJ
N4SU	NW5K	N6DKP	N7CKD	OE6MBG
OH1RY	OZ8BV	PA3DFU	SM4CAN	SM6EHY
SP3GEM	TI5EWL	VE2HQ	VE3BMV	VE7BS
VK6LK	W1FV	W1NH	WB2ITR	W2JB
W3BGN	W4DR	W6NLZ	W6RJ	YU7PFR
ZL4BO	4X4NJ			

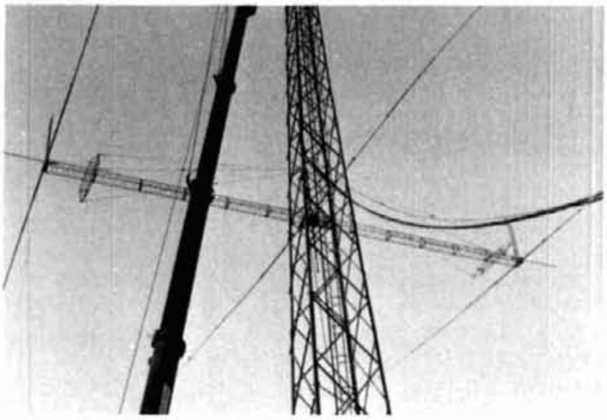

fig. 1. Three full-size element homespun 80-meter Yagi helps produce the outstanding signal heard from I5NPH.

a word on format

Originally, I had considered providing the information in a strictly tabular fashion, following the format of the survey with a list of callsigns and the data in the adjacent columns. But this approach would have required 13.5 printed pages, just for the data! Instead, each category is discussed and tabulated individually, with callsigns provided in some cases.

low band transmitting antennas

Wow! The variety and creativity evident in this area is outstanding and as diversified as the users themselves. One of the reasons people are attracted to the low bands is because it is (or at least was) virgin territory where you cannot simply buy your station and

*A note to the others who received a copy of the survey, but whose names do not appear on the list: if you have not yet sent in the form please do so and the information will continue to be compiled. If a form was not sent to you please consider it an oversight on my part and send for it.

By Rich Rosen, K2RR, Editor-in-Chief, *ham radio*

Table 1. 80 meter transmitting antennas

Antenna type	D/P	Additional comments
Yagi, 4 el,tubing	P	Double driven, W6NLZ
Yagi, 3 el,tubing	P	Full size el,OH1RY,I5NPH
Yagi, 3 el,tubing	P	Loaded el, VE2HQ,K3ZO,W6RJ
Yagi, 2 el,tubing	P	40% full size, N6DKP
Yagi, 3 el,wire	P	Wire added one side,YU7PFR
Half loops, 3 el,wire	P	Versatile system, N4SU
Delta Loop, two element	D	240' per loop,DJ0IA
Delta Loop, single element	-	@135',VE3BMV;@20m SP3GEM
Bobtail curtain, phased 2 bay	D	Vt el=238/freq, N4AR
Bobtail curtain, single bay	D	Remote-tuning cap, SM4CAN
Vertical arrays, 4 elements	D	W1NH, W4DR, K2BT, SM6EHY
Vertical arrays, 3 elements	D	0.125 wave, 2 active,W1FV
Vertical arrays, 2 elements	D	HyTowers @ 0.5 wave,W3BGN
Vertical, quarter-wave	-	63' of Rohn 25, NW5K
Inverted Vee	-	@36',70',OE6MBG
Slopers, half-wave, 3 el	P	1 driven, 2 reflect,LA7ZO
Slopers, half-wave, 2 el	P	Fed 70' apart,WB2ITR
Slopers, half-wave, single	-	@80', VK6LK
Slopers, quarter-wave	-	@100',K5UR
Half Square	D	Fed RG58 upper corner,K2FV
Dipoles, phased	D	Phase 0.25 wave both,K2FV
Dipole,tubing	-	94' rotary,@160' N4RJ
Dipole,wire	-	@50',GW4OFQ
W8JK	D	140' el, @ 65',W2JB

Table 2. 160 meter transmitting antennas

Antenna type	D/P	Additional comments
Vertical plus reflector	P	Elec rotatable, 4X4NJ
Vertical, plus parasitic el	D	Cardioid, SM6EHY
Vertical, quarter-wave	-	Grounded monopole,N1ACH
Vertical, quarter-wave	-	Loaded, DL0WU
Half-wave loops, phased	P	Refl/Dir switching,N4SU
Inverted Vee	-	4" open wire @90',W2JB
Inverted L, phased	D	Hytower with 108' H,W3BGN
Inverted L	-	75' Vert,55' H, VE7BS
Slopers,quarter-wave,phased	P	Driven+3 refl,N4RJ
Slopers, quarter-wave	-	3 switched, KG7D
Sloping delta loop	-	Fed 26' fm corner,W3BGN

fig. 2. JF1IST uses a commercially available model CY-703 (Create Manufacturing) shortened three-element Yagi.

have someone else erect and install a competitive system. It meant — and still often means — climbing to greater heights, literally, and getting dirt under your fingernails. That's changed to some extent with the availability of commercial Yagis for 80 meters, but the challenge and achievement remain. The full-sized homebrew three-element 80-meter Yagi of I5NPH is seen on its way up (**fig. 1**). There is nothing "amateur" about this installation.

Tables 1 and **2** list the 80- and 160- meter Driven and Parasitic transmitting antennas used by a representative sample of those surveyed.

A few notable examples of some very effective 80-meter Yagi installations are apparent in **figs. 2, 3, 4,** and **5**.

low band receiving antennas

As a general rule, those surveyed agreed that two basic types of antennas are used for reception: the elaborate transmitting array or Beverages. That poor, often-repeated statement about verticals working (and hearing in this case) equally poorly in all directions is incorrect. As part of an array, vertical antennas exhibit directivity and discrimination against unwanted noise and QRM.

Beverages, for those who have the space, can also be used very effectively to receive signals from a preferred direction and discriminate against others. A two-wire version, recently known as an SWA and described by Beverage in his original AIEE paper[1] has the additional ability to rotate an azimuthal null. As with any other antenna, Beverages have their supporters and detractors. That they work is indisputable; that most are installed far from optimally is probably also correct.

Table 3 includes details of Beverages used effectively by the surveyed stations. Lengths, terminations, installation heights, preamp use, and callsigns are provided. Though most Beverages preferably are installed over low conductivity soil, OZ8BV proves that they still perform over salt water with his four unterminated 200-meter long antennas.

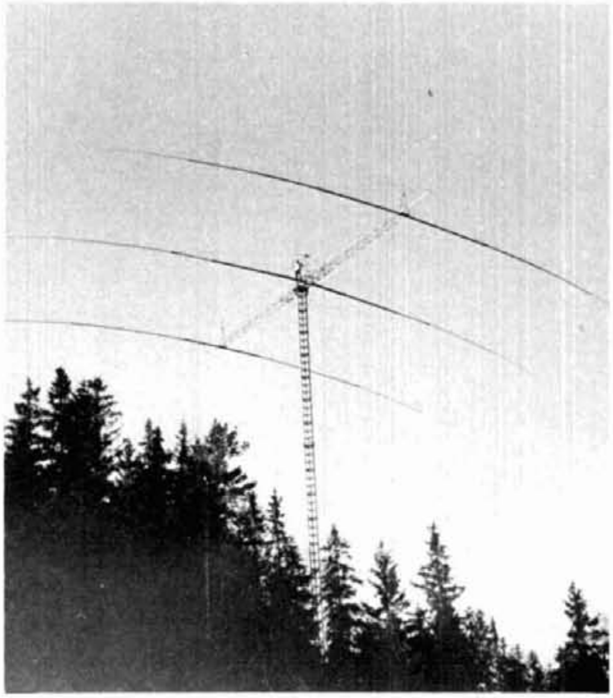

fig. 3. Full size element Yagi is installed "in the clear" and accounts for OH1RY's strong signal from Finland.

Table 3. Low band Beverage receiving antennas

Lengths	Term.	Notes	Callsign
Three @300-600'	Unterm		VE3BMV
Five @540'	450 ohms	20dB preamp	N1ACH
One @800'		10'	4X4NJ
One @390'	440 ohms	8'	VK6LK
One @350'	Bidirect	10',2 #19	VE7BS
Two @750' One @500'			W3BGN
Six @1000'			W1NH
Seven @550'	150-1100	3-12'	K5UR
One		2 wire SWA	SM4CAN
Two @700'		2 wire	N4RJ
One @500'		1 wire	N4RJ
One		2 wire SWA	N7CKD
Four @600'		Reversible	N4SU
Three @500'		Fed both ends	W4DR
One @500'	Unterm	6' +preamp	K1MEM
One @950'		8'	K1MEM
One @450'	450 ohms		W1FV
One @550'	Unterm		W1FV

Table 4. Yagi material description

Nr. of el.	Element description	Wgt.
3 (K3ZO)	90',linearly loaded (KLM)	400#
5 (OH1RY)	142' (R),135.5' (DR),129.7' (D),5 diff.dia. R-DR=37.7', DR-D=34.45' (Homebrew)	1057#
2 (N6DKP)	El 40% full size, DR-R=24' (Homebrew)	
4 (W6NLZ)	90' el, 76' boom (KLM)	
3 (JF1IST)	96.5' max el,50' boom, (Create CY-703)	264#
3 (VE2HQ)	110' lin loaded el, 11 diff dia,65' boom	515#
2 (JA1FRE)	33' boom (Homebrew)	220#
3 (W6RJ)	(KLM)	

Table 5. VSWR bandwidths for typical 80/160 meter antennas

Antenna	VSWR	Bandwidth (kHz)	
3 el Yagi,shorter el	2:1	100 on CW,100 on SSB	(80)
3 el Yagi,full size	2:1	380	(80)
3 el Yagi,wire	2:1	240	(80)
2 el Yagi,40% full size	2:1	60	(80)
Dipole,rotary (KLM)	2:1	100-120	(80)
Vertical,4 el driven	2:1	>300	(80)
Vertical,2 el driven	2:1	>70	(160)
Vertical,130' shunt fed	2:1	40	(160)
Vertical,quarter-wave	2:1	100	(160)
Vertical,quarter-wave	2:1	375	(80)
Half-wave slopers	2:1	250	(80)
Delta Loop	2:1	75	(160)

antenna materials

This broad category discusses the materials used to assemble the previously described transmitting antennas. In general the Yagis use tapered sections of aluminum, if made from tubing, and copper-clad wire otherwise. The verticals using aluminum (6061-T6) or steel masts, or single or multiple bare or covered wires, show more variety. In addition, most of the rotatable Yagis use a combination of aluminum tubing and insulating sections that are linearly loaded by multiple turns of wire. **Table 4** provides data on the rotaries in terms of length of elements, total weight of antenna and miscellaneous details. All of these are for 80 meter antennas. So far, to my knowledge, no one has an operational 160-meter rotatable Yagi.

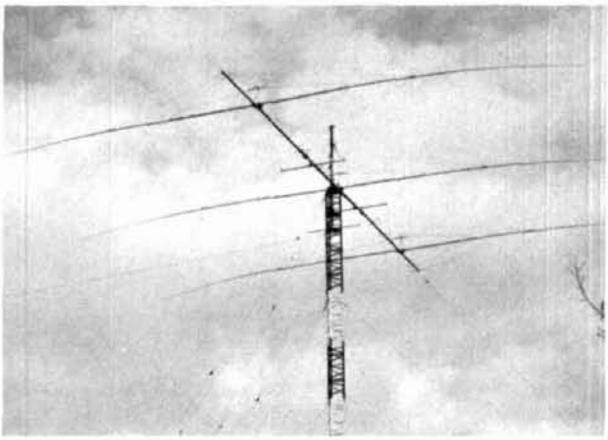

fig. 4. VE2HQ's homemade Yagi uses linearly-loaded elements but still is quite large.

hardware

This category encompasses the large rotaries, verticals and wire antennas. Once again the consensus is to use hardware that will last under all weather conditions. For the Yagis, this implies stainless steel or other non-rusting metals; for the wire antennas, good quality rope that is UV-resistant or "Phillystran." To withstand all weather conditions, liberal use of paint, tape, epoxy, Dow plastic sealant, Copper-kote®, or Coax-Seal® is recommended where applicable. Remember that if the antenna is going to fail, it will most probably fail in the worst weather, during the low-banders' best operating season.

electrical characteristics

The great variety of responses to this question were not only a function of the particular antenna in use but also a matter of personal preference for instantaneous bandwidth operation versus tuning with a matching unit. There were those who wanted only flat 50-ohm lines using coax, and there were quite a few who thought that open wire line and use of a matchbox was a better approach. N4SU summed up the latter opinion with the following statement: "It boggles my mind to think about all the Megawatts of RF energy being wasted in heating coaxial cable on the ham bands in this country." An example of N4SU's approach is shown in **fig. 6** where he uses his multiloop array for 20, 40, 80 and 160 meters.

By my way of thinking, both approaches have their obvious advantages and disadvantages. **Table 5** summarizes some of the achievable VSWR bandwidths correlated with the particular antennas used. This is just a rough guide; VSWR is a function of many parameters.

antenna gain

Another somewhat controversial term is achievable gain. However, unlike the low-banders' higher frequency cousins (with their 10 to 20-meter high-gain arrays), due to the large element dimensions on 80 and 160, the actual variation between lower and higher gain antennas is not too great. After reviewing all the data, the highest gain antenna described, I believe, is the phased Bobtail curtains built by N4AR; he estimated the gain at 7 to 8 dB over a single ground-mounted vertical. The three-element Yagis are not far behind, with those surveyed indicating a range of 5.5 to 6 dB. Next in the gain line are the phased four-element vertical arrays, coming in at between 4.9 and 6 dB, depending upon whom you talk to.

The textbooks provide, of course, the theoretical maximum values, but there are several important points that should be stressed before getting carried away with these numbers. Though the maximum difference in antenna gain between a *big gun* and a *little pistol* on 80 and 160 is around 6 dB, it is not the most important factor in the success story. The true criterion that makes these high performance stations shine is in their ability to *hear* — and I'm not necessarily talking about the use of Beverages.

A four-square vertical array does not have much more gain than a standard (quarter wave electrically and spatially separated) two-element array. But look at their front to back ratios, i.e., their E and H field patterns). The larger system provides considerably more attenuation off the back over a greater azimuthal beamwidth than does the cardioid version. This translates to receiving better and not disturbing others on adjacent frequencies as much if they're not in the beam direction when you're transmitting. It is for this reason, and the fact that it is difficult to quantify the received survey data (without all the parameters and operating conditions being known) that more specific antenna gains are not listed.

Before we leave this subject, that "measly" 6 dB variation in gain mentioned before can, at times, on the low bands, represent an enormous difference. During marginal conditions, even a 1 dB change in signal level can mean the difference between contact and no contact.

front-to-back ratios

Getting down to basics, what determines a high front-to-back ratio? "Front" is where the signals add and "back" is where they cancel, vectorially speaking. Even simple arrays (two elements) can experience a front-to-back (ratio) in excess of 60 dB! However, this is for very specific signal arrival angles (azimuthal and elevation) and polarization on sky-wave signals in particular. A slight change in one angle is all that is needed to upset the relationship. And changes do occur, sometimes over a very short period of time.

More complex arrays, however, can and are designed to produce azimuthal patterns that exhibit deep nulls (30 dB or more) over a 90-plus degree beamwidth. The four-square and the three-element inline are just two examples. The proponents of these driven arrays are quick to point out that they have two major advantages over rotary Yagis: instant direction change (through switching) and better front-to-back and front-to-side values. However, in fairness to the Yagi constituency, there are "Horizontal" nights and "Vertical" nights, and many a time a high horizontal beam has handily beaten the vertical arrays into Europe on the short path. But let's see, in **table 6**, what F/B's have been observed by the actual users of the low band antennas.

polarization

There are no eye-openers here. Both horizontally and vertically polarized antennas are used effectively by the high-performance stations. Due to the large antenna dimensions at these low frequencies, there are more vertical than horizontal *arrays*. However, as pointed out before, there is no one *best* antenna for all propagation conditions, locations, and times. If there were, it would probably have the following properties: instantaneous switching in azimuth, ele-

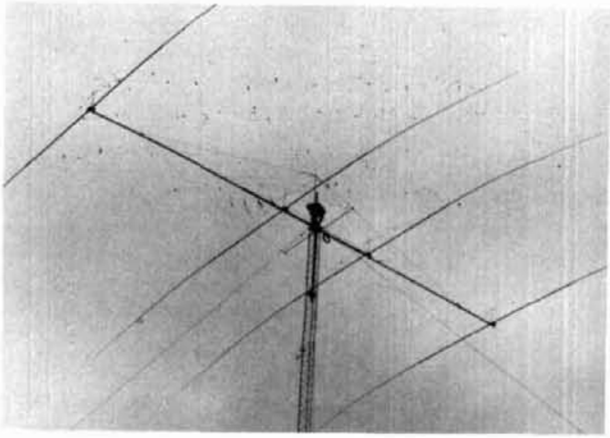

fig. 5. A double-driven element is used in W6NLZ's four-element Yagi, a product of KLM.

Table 6. F/B ratios for low band antennas

Antenna type	F/B (dB)	Comments
2 element Yagi, short el	10-15	JA1FRE
3 element Yagi, short el	10-15	*function of freq.*
3 element Yagi, full size	30	
3 element Yagi, wire	8-12	YU7PFR design
4 element Vert. phased array	30	W1NH
4 element Vert. phased array	15-45	SM6EHY
2 element Vert. phased array	20-30+	W1FV
Bobtail curtain, two bay	15-20	Great F/S
Delta loop, 2 element driven	20	DJ0IA

Table 7. Rotators

Designation	Comments	# in use
Telrex	#BA32899RIHS (Largest)	3
Homebuilt	1:250 ratio, 0.5 rpm	1
Create RC5A-3X3	Manufactured in Japan	2
Modified prop-pitch	Rotates KLM 4 el Yagi	1

Table 8. Support structures

Description	Height	Station
Building plus tower	180'	EA8ADF
Rohn 45	160'	N4RJ
Rohn 80 plus 10' mast	150'	K3ZO
Self-supporting	131	JA1FRE
Rohn 45G plus 10' mast	130'	K5UR
Trees	130'	VE7BS
Westover series XHD	120'	LA7ZO
Tri-ex T-20	120'	W6NLZ
Homebuilt 50' on 60' microwave twr	110'	VE2HD
Telrex Big Bertha	110'	VE3BMV
Heights	98'	N4SU
Create KT-11N	98'	JF1IST
Tri-ex Skyneedle	90'	W6RJ
Trees	90'	K2FV
Rohn 25	78'	K1MEM
Pole	65'	DJ0IA
Buildings	59'	YU7PFR
Self-supporting	40'	TI5EWL

vation and polarization, variable beamwidth control, and no sidelobes. In addition, it would have the capability of being scanned in wider arcs while simultaneously being operated in narrow mode. After daydreaming for a second, even the super stations compromise in this respect. That's basically why many use multiple antennas that offer different polarization and optimum angle of arrival reception capability.

steering

There are two basic means of steering low band arrays: mechanical and electrical. Two or more elements can be made to transmit or intercept signals *from specific directions if certain amplitude and phase* relationships at their terminals are satisfied. This is accomplished through the use of delay lines, lumped components, or combinations thereof. YU7PFR illustrates in **fig 7** his method of "steering" a three-element 80-meter wire array. The specific details have been provided in many articles and books. An excellent treatise on the design and construction process for phased vertical arrays (also applicable to horizontal arrays) can be found in a recent series of articles by Forrest Gehrke, K2BT.[2]

Mechanical rotation of the large arrays is not a task to be taken lightly. It requires careful consideration of many factors, including antenna wind-swept area,

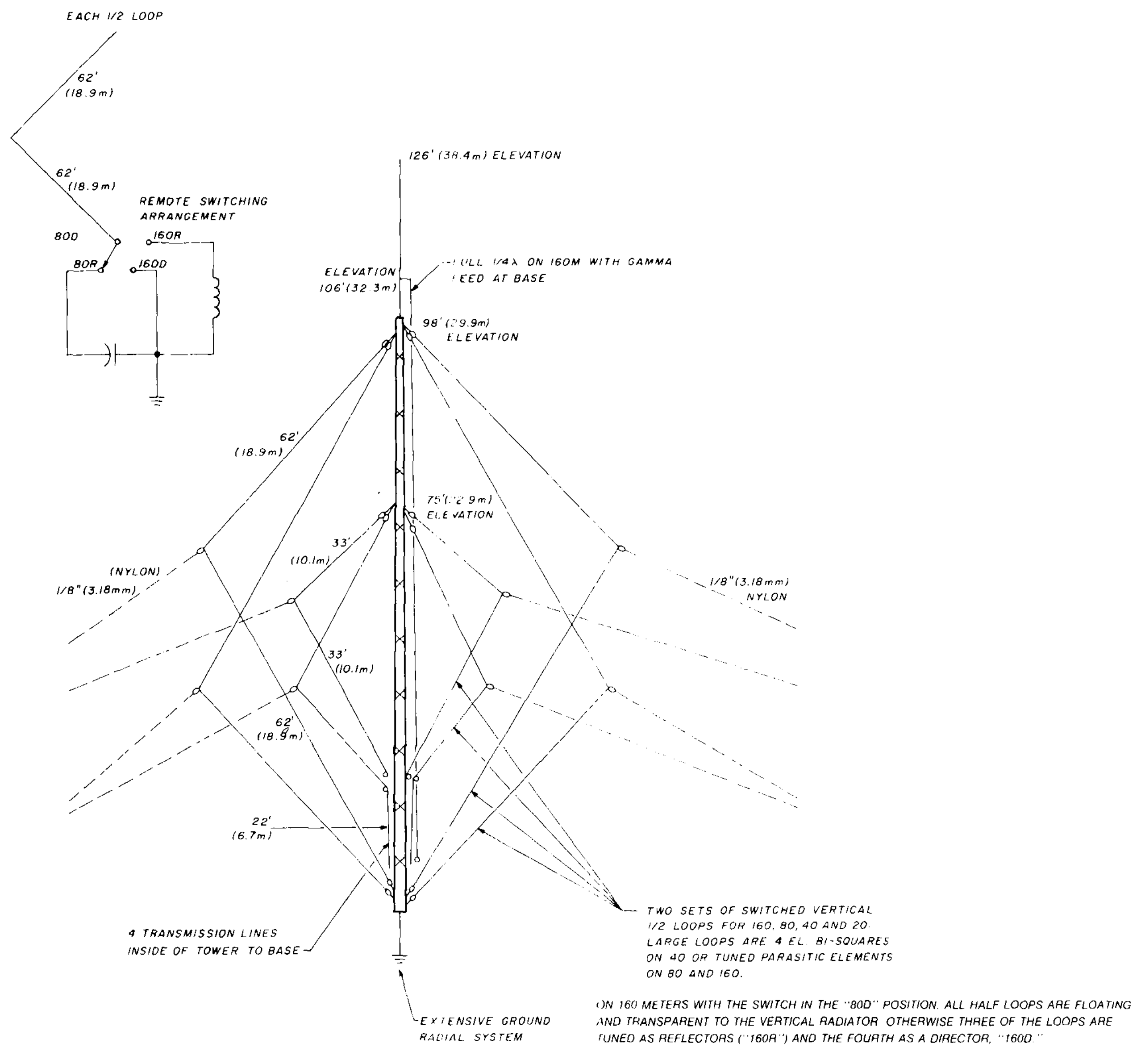

fig. 6. N4SU's multiband antenna array uses open wire line from the elements to the matching units.

mounting height, height above local terrain (i.e., is it shielded by trees from high winds?), weight, mast length, metallurgy, speed of rotation, weather conditions — both average and extreme — and expense, to name a few. To accomplish this task, the rotators listed in **table 7** are used by several of the super-stations. Unfortunately, only a few of these responded to this particular survey question.

skyhooks that support these antennas

Man-made and natural structures consisting of towers, masts, buildings, and trees provide the support for the 80- and 160-meter antennas used by the stations surveyed. Considering the heights required, they probably represent the single greatest installation expense (excluding trees, of course). **Figure 8** illustrates the turnbuckles and guy lines used to tie down a 160-foot tower.

Towers and masts can and often do serve dual purpose as support structure and radiator, as in the case of verticals. The variety of the towers is considerable, with some installations surpassing, in quality, even those used by the commercial radio services.

Many not wishing to avail themselves of commercial units choose to build or modify other existing structures to suit their needs. Those fortunate enough to have tall trees on their property have been able to construct low band wire antennas that compete effectively with tower-mounted aluminum behemoths. On the other hand, it might surprise a few to see how *low* some of the big-gun stations have their antennas. **Table 8** is a compilation of some of the support structures used by the high-performance stations.

When a tower or mast is mounted on the roof of a building, the effective height of the antenna is not necessarily the combined heights. The building roof, depending on its dimensions, electrical characteristics, and separation from the antenna could determine an array factor with a much *higher* takeoff angle than would be indicated by the total height of the antenna above ground. In the case of EA8ADP, his strong signal into the United States would indicate that everything is working in his favor.

ground systems

This perennial question is asked all the time: how large a ground system is needed? The simple answer is *the larger the better*. Unless your antennas are situ-

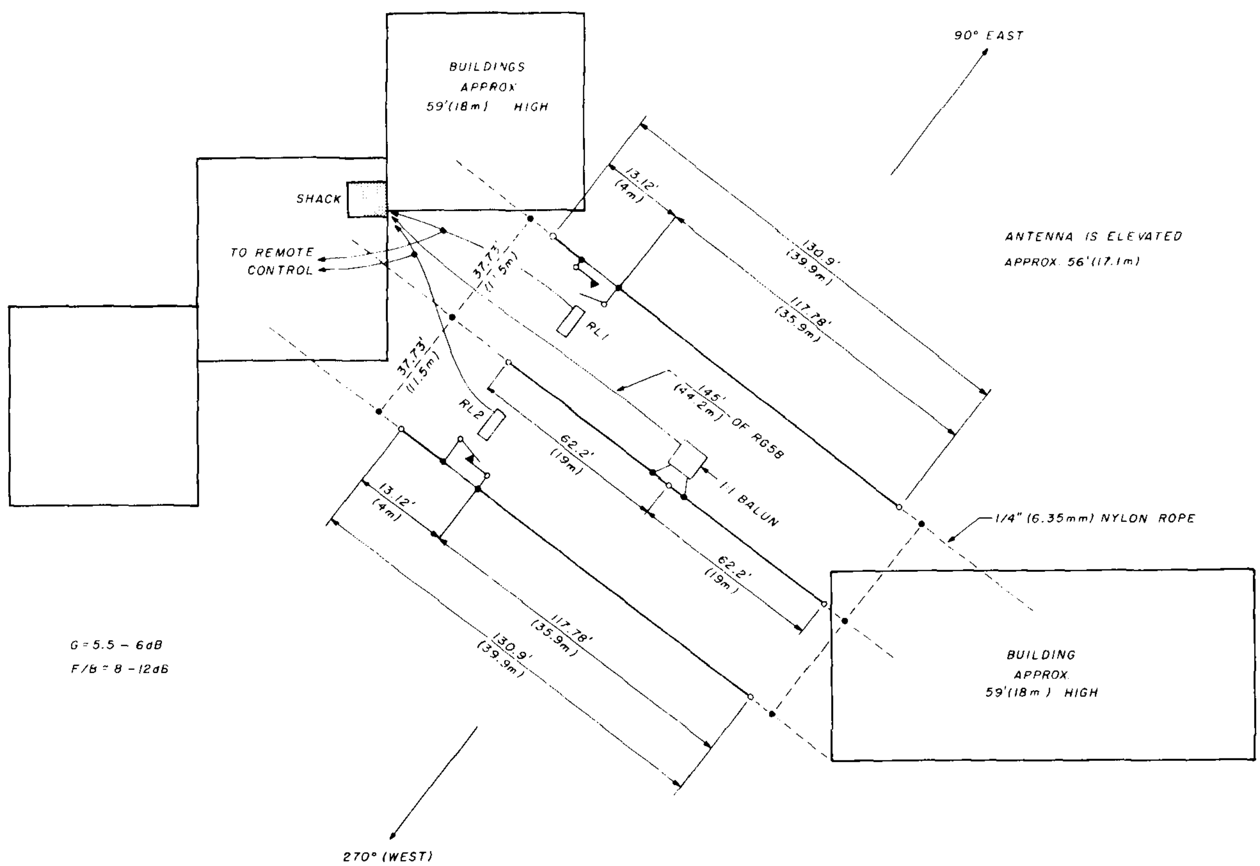

fig. 7. YU7PFR is able to switch antenna firing directions by opening and closing relays.

ated above an infinite extent, infinite conductivity ground plane, there is room for improvement. For those using verticals, two conditions should be met:
1. The immediate area around each vertical should have a high density of wire within a quarter wavelength of the radiators. A minimum of 100 radials is recommended. This determines and stabilizes the zone impedance and reduces losses, which is especially important if the current loop (current maximum) is close to or at ground level.
2. An extended ground or radial system should be installed as long as possible in the preferred transmission and reception directions. This increases the amount of energy present at truly low angles. *How long*, you ask? That's a function of several parameters, including propagation path and mode, distance, far field conductivity and permittivity (dielectric constant), solar activity, state of the geomagnetic field, transmitter power, and receive site conditions, to name just a few. Specifically, if I recall correctly, a six-wavelength radial system will produce a maximum elevation lobe at 6 degrees from the horizon using a single vertical.

SM6EHY suggested that it might be worthwhile to have the capability of remotely switching an extended radial ground system in and out. When switched in, lower angle of arrival signals are enhanced. When switched out, higher angle takes over. This could be accomplished through the use of convenient groundbus point located relays. (Possibly another way to achieve this result would be through the use of *two* concentric ground rings at the antenna — the longer radials being attached to the outer switched in/out ring.) One useful application of enhanced lower angle transmission would be to "sneak under" the auroral high absorption layers. (More on this later under "propagation.")

Those using vertical antenna systems where the current loop is *not* at ground level should still be concerned with providing as large an extended radial system as possible for the second reason, even though, the ground loss resistance term represents a smaller fraction of the total antenna, in this case feed impedance.

A useful compromise for all vertical users is to place a mesh under the antenna as well as a radial system. The larger, of course, the better — but since maximum return currents *want* to exist within the immediate vicinity of the antenna, that's where it's most useful. The mesh, in addition to a 0.25 or 0.3 wavelength radial system, would improve the performance of the composite antenna system.

The existence of an extensive and symmetrical ground system also aids the phased vertical array designer. It eliminates one of the unknowns, or, stated differently, doesn't introduce yet another complex term to deal with. (Warning: before you begin quoting the above statements as gospel, I should mention that the information represents my own educated opinion, based on the work of others, whom, I believe, are correct).

An extensive ground system also aids the horizontal antenna user. It helps establish the distance between the antenna and its image (Green's function) and consequently determines the composite elevation pattern. This represents an increase of up to 6 dB in the total signal (sky and ground reflected wave) at a specific takeoff angle. If this angle is optimum for the particular path, then, in simple terms your signal will be louder at the point of reception and vice-versa. **Table 9** is a compilation of the ground systems used by the super-stations. Notice, however, that only a few of the stations that utilize horizontal arrays have extensive ground systems.

In addition, NW5K uses 30 square feet of chicken mesh; 4X4NJ puts 2 pounds of copper sulphate around his ground stakes, and N7CKD, besides using 55 square feet of chicken mesh and a half-mile of 5-foot (1.52 meters) chain link fence and barbed wire, pours 500 pounds of rock salt and 150 pounds of copper sulphate into trenches that he keeps moist at all times. (I'd be a wee bit concerned about the latter chemical, especially with regard to the possibility of its leaching into the water table).

I personally try to practice what I preach and am presently using 200 radials that vary in length from 65 to 300 feet (20 to 91 meters) in addition to an approximately 1000 square foot (93 square meter) ground mesh. And that's for just one vertical.

soil characteristics

As mentioned previously (see "ground systems"), the importance of a good ground, especially for vertical antenna users, cannot be stressed enough. There are those who are fortunate to have an antenna site whose soil has high conductivity or, even better, a high salt water table close to the surface. Under these circumstances the requirements for both near and far field enhancement are approached. An almost ideal site would consist of a high tower mounted antenna overlooking salt water on all sides.

Notice that vertically polarized antennas have been stressed. Though it is true that horizontally-polarized antennas are affected by a good ground system in the near field, it's the far field conditions of a horizontally-polarized antenna that show striking dissimilarities to that of a vertically-polarized antenna.

A figure of merit can be assigned to the reflective "nature" of the earth's surface in the form of a complex quantity that has both amplitude and phase terms. This reflection coefficient is very different for signals impinging on the earth that are vertically, rather than

Table 9. Ground systems

Radials	Length	Gnd rods	Length	Station
3	125'	3	8'	K3ZO
–	–	3	8'	VE3BMV
2	131'	–	–	PA3DFU
3	135'	4	10'	4X4NJ
65	65' +	–	–	SP3GEM
50	62'	–	–	VK6LK
20	75'	–	–	VE7BS
125	65'	4	8'	NW5K
90	80'	6	6'	W3BGN
–	–	9	6.6'	JF1IST
320	80'	500	4'	W1NH
100	130'	1	2'	K5UR
65	130'	–	–	N4RJ
5	250'	–	–	N4RJ
400	70–1000'	30	10'	SM6EHY
496	65'	–	–	W4DR
15	65'	3	6'	DJ01A
300–360	30–130	–	–	W1FV

horizontally, polarized (i.e., the E-field of the electromagnetic wave is vertical or horizontal by definition). The reflection coefficient is a function of the conductivity and dielectric constant of the earth, the frequency, and the angle by which the wave strikes the surface.[3]

Let's consider three sites and observe the amplitude and phase of the ground reflected component for both vertical and horizontal polarization. The first site is a typical New England location with low conductivity, rocky soil. The second is farm land — the pastoral, low hills, and rich soil typical of Dallas, Texas or Lincoln, Nebraska. The third site consists of an installation over salt water — for example, any coastal location right on the beach. Let's also examine two different angles of arrival (or takeoff); 15 degrees for the long path and 45 degrees for the short path to Europe from the east coast. **Table 10** summarizes the various conditions and results.

For those who wish to replicate the calculations, I used the following soil parameters:

Wavelength: 80 meters
Frequency: 3.75 MHz
Rocky soil: Conductivity: 2 mS
Dielectric constant: 14
Pastoral: Conductivity: 30 mS
Dielectric constant: 20
Salty: Conductivity: 4.64 S
Dielectric constant: 81

Table 10. Reflection coefficient vs soil type and takeoff angle

Soil	Angle	Polarization	Amplitude	Phase
Rocky	15	Horizontal	88% of max	2.00 deg
Pastoral	15	Horizontal	97%	1.63
Salty	15	Horizontal	99.75%	0.14
Rocky	15	Vertical	17%	75.53
Pastoral	15	Vertical	62%	25.02
Salty	15	Vertical	96%	2.10
Rocky	45	Horizontal	72%	6.24
Pastoral	45	Horizontal	92%	4.45
Salty	45	Horizontal	99.75%	0.14
Rocky	45	Vertical	51%	12.44
Pastoral	45	Vertical	84%	8.85
Salty	45	Vertical	98.67%	0.77

interpretation of results

There are a few eye-openers here that help to explain observations made over the years. Did you ever wonder, for example, why stations using a relatively low dipole (50 or 60 feet/15.24 or 18.28 meters) on 80 meters would often be heard just as well as those using verticals working against a good ground screen? Compare the seventh and tenth lines in **table 10**; the ground reflected component of the signal from the low horizontal antenna is actually stronger than the vertical antenna (72 percent of maximum versus 51 percent). Though this was calculated for rocky soil conditions, examination of the other entries shows that the low horizontal beats the vertical for all soil types at a *45* degree takeoff angle.

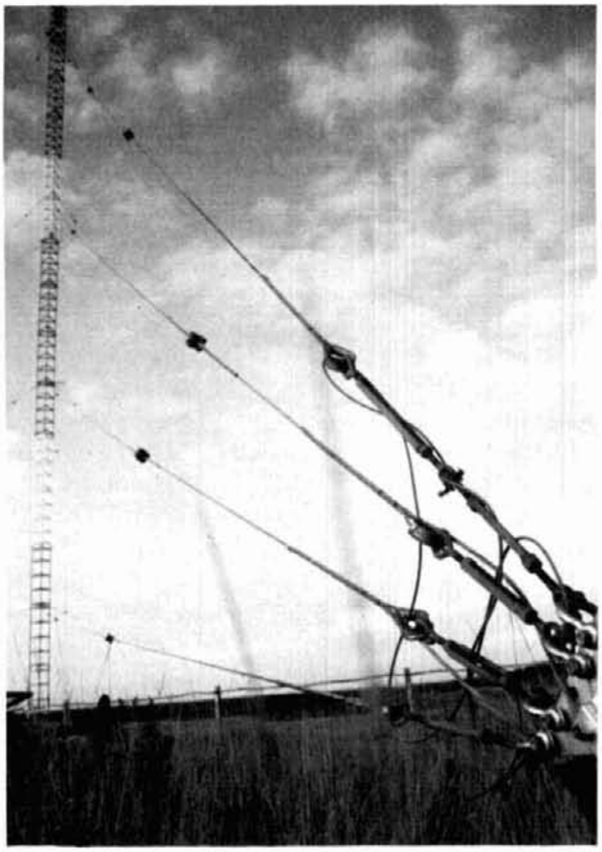

fig. 8. To gain an appreciation of the type of tower needed to handle low-band rotaries, examine VE2HQ's new 160-foot structure ready to support his three-element Yagi.

The situation is even more pronounced for a 15-degree takeoff angle condition. Compare lines 1, 2, and 3 with lines 4, 5, and 6; notice that for every soil type, the high horizontal beats the vertical. However, a horizontal antenna produces a maximum elevation lobe of 15 degrees when it is one wavelength up (250 feet/76.2 meters). There are probably only a few low-banders (WA1EKV, for example) who, thanks to a high tower and local topography, have their antennas at this height. Consequently, for that low-angle, low-path shot, it's perhaps easy to construct a vertical and get approximately the same performance as you would with the high horizontal. (This is true for medium to high conductivity far field soils).

Finally, if you're a lover of verticals, then the importance of an extended radial ground screen becomes apparent when you examine lines 4 and 6 in **table 10.** Copper, an even better conductor than salt water, provides an almost 600 percent improvement in reflected component level. This requires radials several wavelengths long to achieve a maximum elevation lobe of 15 degrees.

Let's say that you're considering several sites that have vastly different soil conditions for your ultimate super-station location. If you favor horizontal antennas, there's not a lot of difference in the reflected wave amplitude as a function of angle or soil parameters (compare lines 1 to 3 and 7 to 9 in **table 10**.)

But why are we so concerned with the reflected component? Simply because the composite launched wave or signal is a combination of the sky wave and the ground-reflected wave representing a doubling in signal level if everything works out. Which brings us to the next point: what factors are involved in maximum signal transmission/reception? The answer is that at the optimum launched angle (takeoff angle) — i.e. the angle best suited for that path, time of day, solar activity, and geomagnetic field conditions — the two components must add constructively. This means that the phase relationships must also match. Now, since the earth looks like a big capacitor, the reflected component always lags (negative phase angle) the incident wave. Notice in the last column of **table 10** the amount of phase delay is listed for the various soils, takeoff angles, and polarizations. It normally follows that if the amplitude of the reflected component is near unity, then the phase angle is quite small.

Upon examining all the survey responses no commonality between soil type and station performance could be discerned. The super-stations run the gamut from rocky to salt water ground characteristics and, in some cases, possibly have chosen their antennas carefully on this basis.

concluding installment

In Part 2 of this article, we'll examine responses from those surveyed to see how they rate their sites, including descriptions of near- and far-field conditions, obstructions, and noise sources with which they must contend.

We'll also consider the danger of lightning strikes and see what precautions these high-performance station operators, particularly those with exposed installations, have taken, both at the shack and at the antennas. Those who've sustained lightning strikes will describe the damage that occurred.

Construction of large antenna systems — whether they be rotaries, long wire antennas, or other elaborate systems — requires extensive planning, labor, expense, and maintenence. What periodic maintenence do these high-performance station operators recommend? Most of these stations have or are using different antennas — how do they compare? Next month, you'll also see how owners rate their stations against the competition. Propagation notes, including some startling results derived from thousands of hours of operating time by those with rotatable and switchable arrays, will be included.

It appears that the days of simple verticals and dipoles are rapidly passing; in our concluding installment, high-performance station owners and operators will describe additional improvements they plan to make to their stations to make them even more competitive in the future.

ham radio

secrets of successful low-band operation: part 2

Careful planning, quality components give DXing's "big guns" the competitive edge

This concluding section examines site requirements, lightning precautions, construction, maintenance, performance, and propagation. In addition, some of the most competitive stations reveal their plans for further improvements.

siting

Though most stations surveyed opt for the highest, quietest location possible, several work within the same constraints that the majority of us (the "little pistols") must deal with. Those surveyed were asked to describe their sites in terms of near and far field topography, obstructions, and noise.

Near field topography is a description of the contours of land in the immediate vicinity (i.e., within approximately one wavelength) of the antenna system. Of those who responded to this question, 83 percent described their near field topography as being flat or having a negative slope; the remaining 17 percent indicated a positive slope. It's important to remember that especially on the lower bands, optimum launch angles often exceed 30 degrees, so perhaps that mountain range in your backyard doesn't have as deleterious an effect as it might on the higher HF bands.

Far field topography in which the land rises at some distance should have an even less pronounced effect on the reception and transmission of low-band signals. However, the actual slope is important (in both the near and far field) and can be determined through the use of United States Geological Survey 7.5-minute (1:24,000) or 15-minute (1:62,500) maps.* Those surveyed described their far field conditions in basically the same terms as near field: flat or negative horizon. For example, they used the words "flat to ocean," "flat many miles," "mountains 26 miles away," "top of hill," "top of ridge," "flat and drops off," "flat to within 1/2 mile in all directions," and "80 meters above local terrain." So you see what most of the big guns have in common: a good site — topographically speaking, at least.

Obstructions. In terms of obstructions on those sites, the worst offender appears to be trees. Yet many of the low-band installations depend on these trees for supporting wire antennas. To date I haven't seen any definitive studies indicating whether the presence or absence of trees greatly affects patterns or performance of low-band antennas. (Any reader who has information on this subject, please contact me.)

Many of those surveyed indicated "none" when asked about obstructions; it's no accident that the FCC at its various monitoring facilities has extremely stringent requirements with regard to the height and location of any obstructions (even in what's defined as the far field). Apparently development of many of the high-performance stations involved site examination and evaluation as a first necessary step. An example of a good near and far field site is seen from the boom's perspective of W6NLZ's 80-meter Yagi (**fig. 1**).

Noise. The oft-spoken adage, "If you can't hear them, you can't work them," certainly applies to low-band operation. (There are some who have a particular knack for working stations that just aren't there, but that's another story). The limiting factor in the reception of signals is noise, be it man-made or atmospheric.

*Maps for areas east of the Mississippi are available in the United States from the United States Geological Survey, 1200 South Eads Street, Arlington, Virginia 22202. Maps for areas west of the Mississippi may be ordered from the United States Geological Survey, Box 25286, Federal Center, Denver, Colorado 80225. USGS maps are also sold by more than 1650 commercial dealers listed in the pamphlet, "Index to Topographic Maps," available without charge from either USGS distribution center listed above.

By Rich Rosen, K2RR, Editor-in-Chief, *ham radio*

After reviewing all the responses and assigning a range of 10 (no manmade noise whatsoever) to 1 (terrible), the average value appears to be around 8. Although most of the high-performance stations have a quiet noise environment, one of the top stations surveyed — with over 300 countries worked on 80 meters and well over 100 on 160 — described his location as "high noise," with a 115-kv high-voltage line within 0.5 mile. Don't give up hope for successful low-band operation if you have a high noise level. If it's the result of faulty electrical equipment, power companies can be helpful in tracking down the source of the noise and correcting the problem.

Other sources of interference can sometimes be located using portable equipment (for example, a pocket AM radio with a ferrite loop or circuit designed especially for that purpose). Noise cancellation techniques have been used for many years with some degree of success.[1,2,3] Many who use directional arrays (phased verticals, for example) probably notice that switching the antennas around produces a noticeable increase or reduction in noise level. Sometimes it's better to point the antenna's null at the interference, trading off a dB or two of gain from the preferred signal direction. A suggestion from some of the veteran 160-meter operators is for newcomers to be aware of noise from TV horizontal oscillators, either your own or your neighbors'.

lightning

The expression, "Into each life a little rain must fall" could be particularly applicable to big guns, whose large antenna systems are more exposed to the elements than others. Lightning poses a real threat to some of these stations, with their high towers and negative horizons. Precautions can be taken, however, and the danger lessened.

Two locations worthy of attention are in the shack and out at the antenna. Precautions taken at the shack include the simple expediency of disconnecting all transmission lines, grounding the equipment and/or antennas or a combination of both. Outdoor precautions include using antennas that are permanently DC grounded by design; for example, the base of a shunt-excited vertical is at DC ground. One method of DC grounding a horizontal wire antenna would be to attach a quarter-wave shorted stub (or odd multiple of a quarter wave) across the dipole's feedpoint and ground it at the shorting bar at the opposite end. This technique, primarily used to drain off static charge, works well only if the antenna is used over a narrow band of frequencies. Otherwise the short reflects back to the feedpoint as other than an open circuit and must be accounted for (in matching). Some of those surveyed were quite satisfied that the grounding system designed as part of their antenna installation would prevent any lightning damage.

fig. 1. Sighting along boom of a KLM 4 element Yagi reveals unobstructed near field topography.

Even if a lightning discharge should occur at your antenna, shack damage is not inevitable. One "big gun" responding to the survey said he felt that by locating the antenna a considerable distance from the shack, the danger of damage occurring at the station end was greatly lessened.

Those who have taken direct strikes reported losses ranging from only a fuse box on one hand to almost total destruction of their home, with walls and windows blown out and ceilings collapsed. Anyone who's ever experienced even a very close lightning strike knows that this is a subject to be taken seriously, with every reasonable precaution applied.

construction

It's one thing to design, on paper, a three-element 80- meter Yagi. It's quite another matter to build, install, and keep it up. Wire antennas, though easier to install, still require an investment in quality materials, labor, and time.

Several of those surveyed built their own rotary Yagis. Noel, VE2HQ, described his efforts to construct his three-element, 515-pound, 43 square foot (windswept area) Yagi, the result of three years of planning, determination, and hard work, marked by several setbacks.

Working all winter in his basement, he built the linearly loaded elements, starting with 3-inch O.D. tubing and down to 0.5 inch in increments of 0.25 inch (11 different diameters). The linear loading was added 125 inches from the butt of each element by cutting the 2-inch diameter section, inserting a fiberglass tube and winding the coil with copper-clad wire. Additional element support was provided by double element guying on each side with Phillystran.**

The boom consisted of two 35-foot long flag poles

*******Phyllystran* is a registered trademark of Philadelphia Resins Corp.

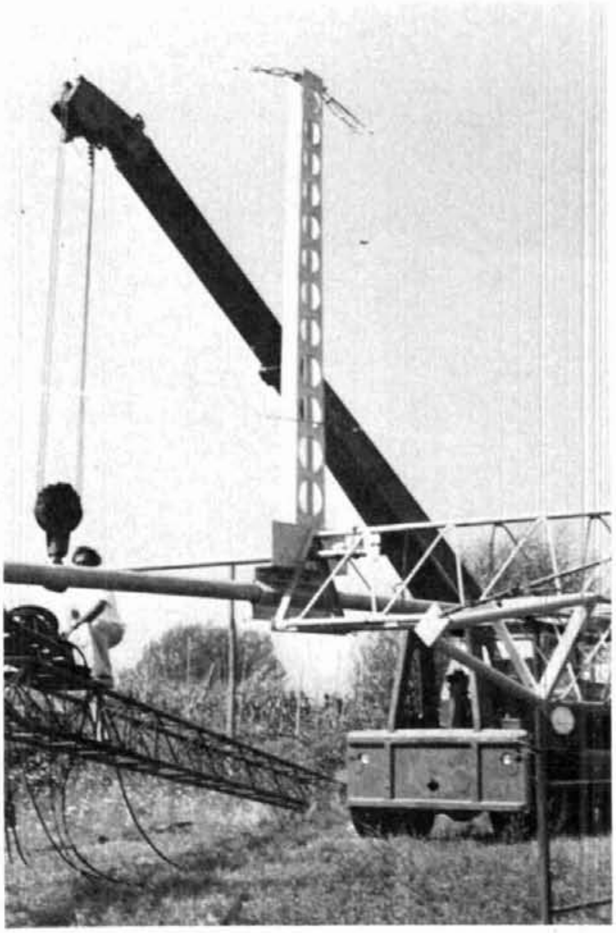

fig. 2. Vertical member and stays prevent element droop.

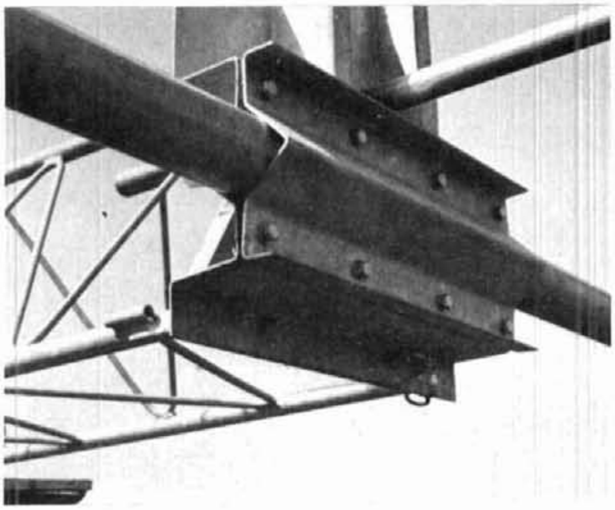

fig. 3. Method of attaching full length elements to boom involves use of 8 bolted through plate for mechanical rigidity.

(4.5 inch O.D., 0.25-inch wall) resulting in an overall length of 65 feet. At this point Noel had to consider what type of tower could support this heavy antenna. He purchased a commercial 60-foot tower designed for supporting large microwave antennas and fabricated a 50-foot triangular extension measuring 33 inches on a side to be mounted on top of that.

The first time Noel installed his antenna at 110 feet, it resonated too high in frequency and had to be taken down. It was made to resonate at 3625 kHz at 15 feet above ground so that it would resonate at 3785 kHz at its final height.

Chris, I5NPH, erected an even larger three-element Yagi using full-size elements. A careful examination of **fig. 2** provides an appreciation of the size of the components used in this antenna. The structure at the right that looks like a tower is the end of the boom; the large tubing at the left, which looks like a large boom, is one of the parasitic elements. Notice the size of the vertical strut used to support the long elements. **Figure 3** shows the method used to attach the parasitic elements to the boom. When one considers the difficulty of installing a completed antenna, eight bolts in the element-to-boom clamp don't represent "overkill."

While W6RJ put his three-element KLM Yagi together on the tower, K3ZO completed his Yagi's construction on the ground and raised it with a 164-foot crane. WA1EKV used ropes strung from his tower in a vee to slide and pull his Yagi to the top.

Because wire antennas tend to break at the worst times, a quick means of lowering and raising them is necessary. Ropes, pulleys, and continuous halyards are successfully used by some to provide this capability. In addition, if you want your antenna to stay up, use the best quality material. One of those surveyed has had success with white/blue marine rope. Polypropylene rope, though less expensive, disintegrates after exposure to sunlight. It might take several years, but it *will* deteriorate; be sure to wear gloves when working with old polypropylene.

installation and maintenance

Two more practical questions were asked of those questioned in this survey: "What precautions did you take in installing your system to make sure it would stay up?" and "What periodic maintenance procedures do you follow?"

In general the consensus of opinion can be summed up in a single word: *quality*. Though topnotch material costs more initially, it delivers years of consistent good performance and pays for itself.

The "big guns" offered specific advice on the subject of non-wire antennas (rotaries and towers). Here's what they recommend:

- Tighten all guy wires and clips to specification.
- Choose all materials carefully — anything that isn't aluminum or stainless steel will rust.
- Paint all towers and masts.
- Lubricate all moving parts properly.

With regard to wire antennas, they advise the following:

- Use quality halyards — for example, white/blue marine rope.
- Use steel line for the halyard section that goes over tree branches.
- Avoid the use of galvanized steel wire for radials.
- Protect all critical connections with a good weather-resistant sealant such as Coax-seal.®

Periodic maintenance procedures include:

- Tightening of guy wires, clips and hardware.
- Lowering wire antennas with pulleys to check the condition of the halyards, wire, and insulators.
- Cleaning insulators with a rag and water.
- Clearing foliage away from verticals.
- Repairing thin wire ground radial systems.
- Protecting systems with the same paint used on the undersides of boats.

Many of the big guns found that they experimented so frequently with new antennas that the short life cycle of their old antennas precluded the need for periodic maintenance.

performance

The next question posed was, "How does your present antenna system perform in comparison to others — either your own or the competition's?" In general most felt that the latest was the best. Specifically:

K3ZO found that his three-element KLM rotary at 140 feet was 25 dB better than a half-wave sloper and up to 8 dB better than his previously used three-element, 80-foot boom delta loop beam.

OH1RY found his full-size three-element Yagi outperformed a dipole by 20 to 30 dB on the long path shot to the United States.

4X4NJ uses four tilted verticals on 160 meters, fed in various phase combinations with passive reflectors to create an electronically rotatable vertical beam system. He feels "it's almost as good as having a full rosette of Beverages, with the added advantage of having a good low-angle rotatable transmitting antenna."

W2JB, another 160-meter operator, stressed the importance of being able to *hear*. "Most of the DX runs low power and signals are usually at the noise level. That's where you need your Beverage antennas," he wrote.

SP3GEM, who trades off between a vertical and a delta loop, doesn't see much difference between the two in the favored delta loop direction. However, he prefers the vertical in other directions — that is, where the delta loop exhibits a null.

KG7D, like many others, believes slopers provide good performance by launching a low angle signal, showing nulls off the sides, and having reasonable feedpoint impedances and consequently high efficiency.

One of the truly big signals from Japan on 80 meters, **JF1IST**, uses the Create Manufacturing CY-703 three-element Yagi and is very pleased with its electrical and mechanical performance. The specification sheet lists its forward gain, F/B ratio and 2:1 VSWR bandwidth as approximately 8.5 dBi, 20 dB and 100 kHz, respectively. JF1IST has his centered on 3.80 MHz, right in the middle of the Japanese SSB window.

W1NH, formerly W1SWX, can often be heard pulling out the rarest of stations on 80 meters, thanks to his three slopers and inverted vee from a 100-foot skyhook and six 1000-foot long Beverages. To illustrate its performance, he enclosed copies of QSL cards from VS5MC, HS5ABD (both short and long path) and JT0DAQ — all very difficult shots from the East Coast on 80.

K5UR attributes his success on the low bands to a superior receiving capability (Beverages once again). Considering that he holds the *CQ* Worldwide DX Contest U.S. record on 160 meters, his transmitted signal must also be outstanding to be heard above some of his competition on the East Coast. He does mention that his new 130-foot vertical appears to work noticeably better than his old 70-footer.

YU7PFR's three-element wire Yagi at 56 feet outperforms his previous single vertical or dipole while providing a 2:1 VSWR bandwidth of 250 kHz. With one of the strongest signals from Yugoslavia, he's consistently heard in the United States.

SM4CAN has noticed as much as a 6 dB improvement in signal level using his Bobtail curtain as compared to his gamma fed tower with 120 radials. However, on long path to the United States his delta loop performs better than the Bobtail *during the month of November.*

According to **SM6EHY**, it's possible to have too low an angle radiator. He says that his four-element phased vertical array just doesn't have that extra punch when high angle signals are propagated, and goes on to say that "the greatest advantage in using phased antennas is that you can reduce noise and QRM pickup from unwanted directions to such a degree that you can hear everything on the band."

VE2HQ compared his home-brewed three-element Yagi with a sloper at 155 feet and found the Yagi to be superior in terms of signal strength. He also estimated the front-to-back ratio to be 22 dB.

With over 300 countries worked on 80 meters, **W4DR**, in comparing his four-element phased vertical array with other antennas, says he believes that the really high horizontal beams still have the edge. **N4AR** uses a pair of phased Bobtail curtains on 80 meters and finds that the F/B ratio on low-angle signals is often in the 15-20 dB range and the front-to-side is "astronomical." He prefers this antenna over Beverages for receiving as well. He also says that having an antenna with noticeable gain and a very definite controllable pattern has provided him with insights on propagation on 80 meters. He's probably one of the few to have worked Laos (XW8BP) on 80 from the East Coast . . . .

Attributing his success to a two-element delta loop array, **DJ0IA** says he's experimented with other antennas but keeps on coming back to it.

W1FV, showing true ham ingenuity, fit a well-designed and constructed phased vertical array into very narrow confines without any compromise in performance. He rates its overall performance on 80/75 meters as excellent. Winner of the single-band category in the 1984 *CQ* WW CW contest, he observed: "The vertical array is the best antenna I have ever used for the difficult paths (central Asia, Japan, deep Pacific, and Indian Ocean)." He has tried many slopers, high dipoles, and delta loops but finds the present configuration to be the best.

EA8ADP proves that sometimes a simple antenna can be a top performer if other conditions are met. His inverted vee has accounted for 225 countries worked on 80 meters in less than three years. He can normally be heard in the States when the rest of Europe is barely being copied. His inverted vee is supported at the 33-foot level on a tower atop a 148-foot high building situated on top of a hill.

propagation

As far as I'm concerned, this has to be one of the most interesting areas considered in the survey. The perspective gained by being able to review responses from different countries, continents — and in general, both ends of a communications path — starts to explain observations made over the years but not understood. I feel fortunate to be the compiler of this information and I'll try to convey some propagational correlations and leave the rest to you. A special vote of thanks is due to **SM6EHY**, who provided an extremely detailed account of his observations made during 20,000 hours of listening on the low bands.

160-meter propagation

For those not familiar with 80 and 160 meters, there is a tendency to lump them both together as "those noisy, short-range bands." That static exists on the lower frequencies is undeniable; that the communications range is limited is true sometimes, but not always. How else could one explain stations working over 300 countries on 80 and 200 countries on 160 meters, given the right conditions and activity? Furthermore, 160-meter enthusiasts are quick to point out that there's sometimes a world of difference between propagation modes on 160 meters and on 80 meters, and that one band should not be judged by the performance of the other. **K1MEM** best expressed this when he said "The basic creed is, don't go by 80-meter conditions to judge 160. 160 can be great to Europe or Africa when 80 is poor and vice-versa. QRN on one band is no indicator of the other. Also the beacons from Europe seem to have no relation to Amateur signals."

K5UR finds propagation to be best towards Africa and the Indian Ocean in the early evenings. At this time of day he's occasionally observed long path signals from Asia (YB, 9M, . . .) coming from the direction of South America. The same stations are also heard on a skewed path at a bearing of 235 degrees in the morning. Signals from Russia appear on a bent path with a heading of 75 degrees.

From the northwest, **KG7D** believes that chordal propagation is the mode on 160 when Europe is being heard at his QTH, yet not being copied at other locations in the United States. He believes this occurs when the F1 and F2 layers fail to merge. "It would be nice to know the optimum takeoff angle for chordal propagation. For me it appears medium angle north/south, low to the east, and again medium angle to the west. Frequent openings do definitely occur along the terminator lines, with signals coming from over the poles. Frequently we see enhanced propagation effects from the auroral zone."

VE7BS found a good opening occurring to VK almost every day throughout the summer of 1985. It started well before his sunrise and ended well afterwards. The observation of this path, he believes, is largely a function of the operating habits of Australians, pointing out that in June and July, VE7 sunrise occurs at a reasonable time in the VK evening. At other times of the year — for example, when VE7's sunrise occurs at 1430Z — the VKs have already gone to bed . . . thus no communications. But the path may still exist. This is somewhat analogous to a tree's falling in the forest; is a sound made even though no one's there to hear it? The answer is an emphatic *yes*.

SM6EHY echoed this same point in discussing the polar path between Sweden and stations on the East Coast of the United States and in the Midwest. Stations can be worked from 0800 to 1200Z on 80. Bjorn believes that the same conditions should hold true for 160 and attributes the lack of contacts to the low level of activity in the northern United States at this time. Bjorn also wishes United States Amateurs would improve their receiving capability; for example, on the 10th of June he failed to attract the attention of W9s after 15 attempts. He also feels that 160 can open up on occasions to a degree that has never been observed on 80 meters. For example, ZL3GQ was 599

+10 dB at 1652Z on December 24 for about 1 minute. The best he's been able to observe on 80 was 589 over both the short and long path.

80-meter propagation

Consisting of two DX segments separated by approximately 300 kHz, 80 meters sometimes also acts as if it were two different bands. Conditions can be excellent on the short path to Europe on SSB and poor on the CW portion and vice-versa.

More responses were received for this band than for 160 meters. Consequently the subject is divided into several sections: short path, bent path, long path and other influences.

• **Short path.** For the most part, those surveyed concentrated on the unusual paths either long path, bent, or skewed. Perhaps it's because the normal great circle path is in reality not all that common or at least certainly not as exciting. If one assumes that several "short paths" exist between two locations at the same time and one path is more severely attenuated than the other, then it's reasonable that the latter path (non great-circle) will be observed as the only path and classified as a bent path. For example, suppose a station in New Hampshire is in contact with a station in the U.K., and that they're both using single verticals. If at the time of the QSO the geomagnetic field is disturbed and the normal great circle path, at a bearing of 54 degrees, is severely attenuated, then signals coming from the second path, off the coast of North Africa, will provide the only viable means of communications. This situation, which has often been observed over the past several years from K2RR to the U.K., normally coincides with a fairly high K index. However, even the latter path disappears at still higher values of K approximately 24 to 36 hours after a major solar event. It's at these times that only signals from the South can be copied and usually only unilaterally. A case in point was during the recent Revilla Gigedo dxpedition, **XF4MDX**. It was as if a traveling blanket of absorption was moving from north to south. A few minutes after the fortunate contact, the signal from XF4 simply vanished. One could observe this effect by listening to which stations were able to get through W1 to W2 to W3, etc.

From his location in Louisiana, Mike, **NW5K**, is able to work into Africa between 0330 and 0630 and into Europe between 0600 and 0700Z via the short path.

Roy, **ZL4BO**, finds that the normal short path into Europe can vary as much as 30 degrees during his (southern) winter.

bent path

The term "bent path" can probably best be explained by saying what it's not: it is *not* a short or long great circle path. Can we then consider the vast number of other possibilities as bent paths? Were it only that simple! Perhaps it's more accurate to say that any path that's strictly not great circle, short or long, contains some element of bending. Remember, the distances covered in some cases are to locations more than halfway around the globe, where the time-varying ionospheric layers are in a different state of flux. Perhaps the signal starts out on a great circle path, only to be diverted by conditions along the way. Maybe this also explains why some of the paths appear to be unilateral or one-way; wouldn't conditions between the stations have to be the mirror-image of each other to be reciprocal? One way to analyze this effect scientifically might be through the use of simultaneous encoded transmission beacons, each with its own directional antenna at both ends of each path, with each transmitter keyed to an atomic clock. Precise time measurements would then determine the path interval and at least its length. But this, some might say, would take the fun out of Amateur Radio. Isn't it the unpredictability of the arrival of signals from exotic locations that makes DXing so exciting?

But I'm straying from the subject. Let's get back to which bent paths, under what conditions, have actually been observed.

Using a three-element Yagi, **W6RJ** observes that most northern European openings are bent somewhat to the south. Furthermore, he states that two stations with coinciding sunrise and sunset times can communicate 90 percent of the time, in the absence of high QRN levels.

ZL4BO attributes his success in bent path propagation to his extreme southern latitude, utilizing the path over both the North and South Poles when the normal (short path) and long path conditions aren't good.

SM4CAN notices that the best direction for working United States stations "short path" is at a bearing of 270 degrees as opposed to the indicated 330-degree great circle azimuth. During auroral conditions, he has worked W6NLZ with signals appearing to come from South America; this correlates with Peter's (W6NLZ) observation from his end of the path.

N4AR has observed signals from Japan, Hong Kong, and Indonesia from the Southwest. In fact, he always hears VS6DO and YB5ASO more strongly on this bent path than from the great circle direction. "This bent path is clearly in the direction of the terminator line [Gray-line — Ed.] and somehow these far eastern Asiatic and Pacific signals scatter into the terminator line path," he says.

Using his full-size three-element Yagi, **OH1RY** observes signals from Hawaii at a bearing of 90 degrees (east), whereas great circle calculations would indicate a northerly direct path.

W1FV, as well as many others on the east coast of the United States, has observed the same bent path towards Japan and Southeast Asia in the morning by beaming to the southwest. Not only have other stations observed this path, but they've also seen it change abruptly (within a matter of minutes) from the southwest to the northwest when hearing Japanese stations. Using a rapidly switched phased vertical array, John finds that it often exhibits ill-defined directional characteristics for long-haul paths around sunset and sunrise, although the antenna is otherwise quite directional. "Perhaps this is explained by multipath propagation or some unusual radiation-angle and/or polarization effects?" he wonders, adding that "this ill-defined directionality is also noted on most signals during periods of a disturbed geomagnetic field."

long path

It's not uncommon to hear stations calling CQ long path around sunset from the east coast. What are they hoping to accomplish? And what's this phenomenon called "long path?" It's reasonable to assume that the practice first gathered momentum with stations on the higher HF bands — for example, on 20, 15, and 10 meters years ago. They observed that it was possible to contact stations by pointing their highly directional antennas in the opposite direction of the great circle short path. At the time very few stations on 80 meters had directional antennas and it was even less likely that *both* stations at opposite ends of the path would have directional arrays. That long path contacts occurred on 80 meters in those years was, however, certain; they just weren't called "long path." (I would like to hear from anyone who operated 80-meter long path years ago.)

N4RJ, W4DR, K2FV and **W1FV** have been able to work into western Australia, Indonesia, and Japan at their sunset by beaming southeast, utilizing primarily the "long path."

From the other side of the path, **VK6LK** finds that his long path opening to the East Coast of the United States normally starts about 15 to 20 minutes after his sunrise and lasts 20 to 30 minutes when the conditions are good. "My first long path opening was with W1FC on 13 September this year, and I would expect the path to close sometime next May. One problem here is short skip from YB. They can drown the weaker long path signals from the United States." From Japan, **JA1FRE** has also noticed the existence of a US-JA long path through his (reception) observations of east coast United States stations at 2130Z.

Other, long path shots not well known by US stations of course still occur. **JA1FRE** works into the UK and Scandinavian countries at 0800Z, taking advantage of this mode. **SP3GEM** and other European stations are able to work into the Pacific areas using the long path. **K5UR** has a morning long path into Europe that isn't too common, but when it does occur, produces high signal levels.

Using his phased Bobtail curtain, **N4AR** has shown how reliable the early morning long path into central Asia can be. He has maintained a schedule over the years with **UL7GW**, talking to him approximately *100 times per season* using this mode. "During that period, many other Asiatic Russians were easily worked on a daily basis," he wrote. Besides these USSR stations, he also worked **XW8BP** and other southeast Asians at this time of day.

What's even more interesting is that he found that the path essentially disappeared during the sunspot *minimum* of 1974-1975. This is contrary to the widely accepted belief that sunspot *minimum* years provide the best low-frequency DX. N4AR commented, "While stronger signals (during this period) were evident from Europe in the evening and an occasional UA9 or UL7 QSO was possible in the evening, for all practical purposes the morning long path disappeared."

As stated earlier, this path returned during the most recent solar maximum. Fortunately at that time, **HS1ABD** and **UL7GW** were again active, serving as markers for band openings.

N4AR remarked that with the phased Bobtails, "There's no question deciding if signals are indeed coming from the direction of the long path. This tends to be along the terminator line during the 1130 to 1230Z window. Looking at the MUF limited F2 hops doesn't seem to explain the loss of signal (during sunspot minimum) adequately. In any event, it's certainly a real phenomenon, at least from this part of the world."

SM6EHY disagrees with the contention that a true long path condition exists with signals *originating* and *terminating* in the same hemisphere. "Long path — with the meaning of true long path direction — does not occur on 80 meters," he wrote. Signals arriving at SM6EHY's QTH from KL7, KH6, VE7, W7 and W6 have the same azimuth angle: 110 degrees. "They arrive at a very high angle (50 to 60 degrees), with some noticeable echo. This holds true only for the same hemisphere. Signals coming from the southern hemisphere have all true azimuth angles for both short and long paths." He also believes that at W0, W6, and W7 sunrise, stations should not be beaming long path but using the Arctic path instead.

other influences

Through his 20,000 hours of low-band observations, **SM6EHY** credits the significant influence of the aurora on propagation. "The conditions this far north are very heavily affected by aurora with regards to paths to stations in the northern hemisphere such as JAs and Ws. The maximum particle radiation from the sun (which causes the aurora) is predicted to occur approximately two years after the sunspot maximum. In this last cycle the aurora has consistently occurred from December, 1981, until now (March, 1986) leaving the polar path open only on special occasions." When this polar path is open SM6EHY can work the east coast and midwestern United States from 0800 till 1200Z. Japanese stations can be worked 24 hours a day. This occurs from mid-November until mid-February, when the path is open.

where is this auroral activity?

SM6EHY continued, "The aurora expands between Spitzbergen (JX) and northern Norway (LA) and under most conditions the maximum activity is experienced close to 64 degrees N (latitude). From 144 MHz observations, the reflection belt travels from the far east through the north to the west and then disappears. Occasionally, it's the other way around.

Bjorn went on to mention that the aurora can change very rapidly — within a period of seconds — virtually closing down a good path. When the auroral activity is *south* of his location the "arctic is like an open field where signals experience very little attenuation."

what other paths does it affect?

"A bent path has been observed during auroral activity," Bjorn wrote. "The signals coming from W1 [stations] just cannot travel through the arctic region [the auroral can be considered to be a 0 to 30 dB pad, depending on the level of activity and signal path — Ed.] and must be reflected in an area close to the equator and other places at the same time. This causes the signal to be heard with some echo and QSB."

benefits of a low-angle radiator

With his phased vertical array and large ground system, Bjorn feels he's able to launch an extremely low-angle signal that can go *under* the aurora's attenuation belt. "The lower you go in frequency, the more important is the takeoff angle; the angle fluctuations are more pronounced at lower, rather than higher, frequencies," he said.

Bjorn believes it's important to transmit at angles between 0 degrees and 10 degrees on 80 meters. "A low takeoff angle antenna can be used very effectively during auroral activity to contact some stations at least *part of the way* through the auroral region. A case in point is when he's not able to hear the W1s, but can still work OX or VE8 stations with good signal strengths."

ducting

Another propagation mode noticed by **SM6EHY** and others involves signals entering at one location, traveling and being trapped between ionospheric layers, and finally exiting at a second location, whereby stations in-between cannot copy either end point. Specifically, on north-south paths signals from stations as far south as 15 degrees follow normal paths. Further south, ducting appears to occur. There are times when Swedish stations north of SM6EHY are able to communicate with South Africa but not be heard by him.

Ducting also possibly occurs on the North Atlantic path between the east coast of the United States and Europe. This might explain the high signal strengths received across the Atlantic by stations using low dipoles that launch high-angle signals. If it were simply a case of multihop propagation between the ionosphere and earth, signal levels would be lower. However, reflections *between* layers, on the other hand, would account for less loss. The entrance and exit requirements for ducting might be high-angle.

when are low-band conditions best?

SM6EHY echoes the sentiment expressed by N4AR that low-band conditions are probably best during the period of maximum solar activity (sunspot maximum). He explains that it's probably not noticed, since proportionately fewer stations operate on the low bands when the MUF is high and 10 through 20 meters are more heavily utilized at that time. It's possible to test this hypothesis during the next sunspot maximum, because there'll be more stations on than ever before using high-performance directional 80-meter antennas.

disturbed geomagnetic field affects path

N4AR kept close track of WWV's A and K indices for many years and believes that neither the bent path nor the great circle long path appear to be beneficially influenced by geomagnetic disturbances. However, with the onset of a geomagnetic field disturbance, spectacular increases in signal strength are occasionally evident over the short path. Also observed by others, the latter situation is normally a precursor of the arrival of the lower energy electrons from the sun 24 to 36 hours later and its associated high level of D layer absorption.

plans for the future

Because improvements are always possible in any station — big guns not excluded — the final question asked in the survey was "What improvements are you considering making to your station?" The responses to this question included ideas for improving receiving capability, installing higher performance transmitting arrays, increasing tower height, using a bigger radial system, installing lower loss transmission line and even acquiring a better site.

• **Receiving capability improvement. K3ZO** wants to improve his 160-meter reception in general. **N1ACH** wants to lengthen his 160-meter Beverages from 1.5 to 2.0 wavelengths. **4X4NJ** looks forward to an improved R4C for 160 meters. **SM4CAN** wants to use better Beverages. **N4RJ** feels that his Beverages could be better tuned and that adding a preamp at the antenna would help. **K1MEM** will terminate his Beverages and run additional ones SE and SW.

• **Transmitting array improvement. VE3BMV** wants to put a two- or three-element quad on his tower. **OH1RY** wants to install a two-element shortened 160-meter rotary. **OE6MBG** would like a two-element driven IV beam; **K2FV**, an additional half square. Phased verticals or phased delta loops would please **SP3GEM**. **KG7D** plans a three-element 160-meter parasitic vertical array using shortened elements. **JF1IST** would prefer a four- or five-element 80-meter rotatable Yagi. **DL0WU** wants a three-wavelength on a leg 80-meter rhombic; **K5UR**, a two-element phased 160-meter vertical aray. **YU7PFR** would like to construct four- or five-element wire Yagi, and **SM6EHY** a four-element 160-meter phased vertical array. A three-element full-size 80-meter Yagi at 160 feet would interest **VE2HQ**; **JA1FRE** would enjoy a two-element full-size Yagi. **W4DR** wants an 80-meter horizontal beam at 150 feet. **W6RJ** plans to raise his existing 80-meter three-element Yagi on his tower.

Other items on the big-gun wish list include increasing tower height (**PA3DFU**), adding more radials (**W3BGN** and **W1FV**), and using lower loss cable; **W1NH** wants to switch to hardline coax to reduce losses on his 500-foot run to the antenna. **WB2ITR** expresses a commonly felt need for a new site, one that has more land and better topography.

conclusion

Well, now we have it: the secrets of successful low-band operation. Well, not quite. One necessary ingredient that's hard to quantify is, of course, the desire to succeed — in this case, to have the very best signal on the band. Besides the other three factors mentioned before (hard work, time, and expense) there's also the dream, the enthusiasm that keeps you climbing to greater heights, laying out just ten more radials and extending that Beverage even further, hoping that one night as you're scanning, that BY4 will come pounding through on 3.505 with a never-before-heard clarity and strength.

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