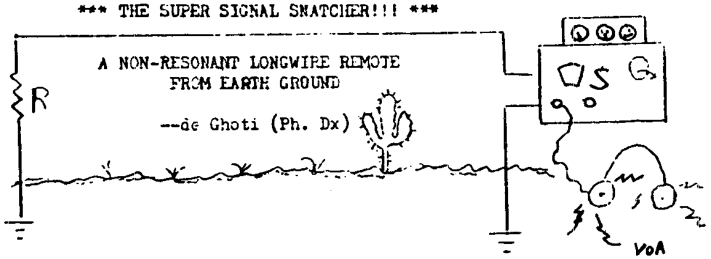
*** THE SUPER SIGNAL SNATCHER!!! ***

A NON-RESONANT LONGWIRE REMOTE FROM EARTH GROUND

--de Ghoti (Ph. Dx)



Otherwise known as the terminated Beverage Antenna, this super signal snatcher can be erected with very little difficulty provided sufficient land is available. In recent years, BCB DXers have used this type of antenna and their very out-of-the-ordinary receptions have been listed in both DXN and DXM.

The purpose of this article is to present a bit of the theory of operation (simplistic), to present some "paperwork" evaluations that can be made for performance estimation prior to construction and to describe one manner of construction which has proven quite practical.

The configuration for this antenna is very simple: a long long wire is erected as close as possible to a given fixed height above the ground and run as straight as possible in a given direction. Two views are shown in Figures A and B with length of wire L (feet), height above ground H (inches), wire diameter D (inches) and orientation for reception of signals from the general direction of A° azimuth.

Bidirectional operation can be had by removing the resistor R at the expense of directivity and hence gain. However, unidirectional operation is assumed here as it is most likely the desirable mode of operation.

Almost all antennas require a ground plane of high conductivity for greatest performance and belong to the huge general classification of E-field antennas-i.e., the most important component of the electromagnetic (radio) wave is the electric component. The loop antenna, on the other hand, is about the only H-field (magnetic) antenna in that, in theory, it derives its performance from the magnetic component.

Consider Figure C. A wavefront W travels in the forward direction of W (the pointing vector) where W = E X H, W is normal to the plane formed by E and H which are themselves normal to each other. As this wavefront passes along and above the ground (earth) plane G, E can be broken into horizontal (EH) and vertical (EV) components. The vertical component induces no currents in the antenna but EH does so that as the wavefront travels along the path of the antenna and the finite ground constants cause W to tilt more and more towards the vertical and thus E toward the horizontal (hence decreasing EV and increasing EH--desirable!), the greater the "signal" induced in the antenna. Ground with poorer electrical properties tilts the wavefront more than earth with good electrical parameters. Hence, the Beverage is expected to perform better over poorer ground--exactly the opposite of what one would naively expect!

The directional properties of the antenna can be explained in the following simple manner: In Figure C, as depicted, W is progressing from end A to end B, so if a RX is connected between B and ground (earth), the "signal" EH would appear at its antenna terminals. If the RX were replaced by a resistor R of a certain value, the "signal" energy would be almost entirely dissipated in the form of heat. Suppose now end B was not connected to either R or a RX and was left "floating"--not connected to anything--and a RX was connected at end A to earth ground. The "signal" travelling from A to B would "run out of wire" (see an impedance discontinuity) and it would be in large part reflected back along the wire to arrive eventually at A as input to the RX. Thus, with B "floating", wavefronts travelling from A to B and from B to A arrive at the RX--bidirectional operation. To restore unidirectional operation then, RX at A, a resistor is placed at end B to ground, thus suppressing the wavefronts passing from A to B but allowing those from B to A to arrive at the RX. That is, in the unidirectional (That is, in the unidirectional) mode, the antenna receives best from the general direction the antenna is "pointing"--the direction of the large arrow in Figure B.

As a point in terminology, this type of antenna is often referred to as a travelling wave (longitudinal with the wire) antenna as opposed to the much larger classification of standing-wave mode antennas.

To be correct, the termination required at the remote or far end of the antenna is not purely resistive so perfectly a network is required. However, it is not practically possible to totally terminate the wave progressing along the antenna to its remote end because the components of this terminated network depend upon the distributed parameters (constants per unit length) of capacitance, inductance, resistance and conductance, several of which vary with frequency so that the characteristic impedance (termination required) varies somewhat with frequency. Nevertheless, for almost all BCB applications of the Beverage, a simple fixed value resistor will suffice quite well. (Note: there is no great practical reason why RXs-possibly in conjunction with a modified value of R-couldn't be operated on both ends of the antenna thus DXing both directions simultaneously and each in the unidirectional mode.)

The value of the terminating (carbon) resistor can be well approximated from the following simple equation (for an infinite highly conducting wire above an infinite infinitely conducting ground plane), viz:

$$R = 138 \log_{10} (4H/D) \quad \ldots\text{ohms}$$

where H is average height above ground and D is wire diameter. Units for D and H are unimportant as long as the same measure is used for both. Several DXers have proposed the use of a carbon base potentiometer (variable resistor) at the termination to be used to "tune" the system--it is thought that this will not likely produce noticeable improvement in performance. Table I lists values for R at most BCB applications of the Beverage--standard resistors within 20-40 ohms or so of the table value should work as well.

Most likely the greatest factor of importance in the performance and construction of this antenna is that of the earth ground at each end. Here lies the dilemma: the poorer (electrically) the soil the better the expected performance of this antenna, but the more difficult it is to obtain a good, highly conductive, earth ground. However, in any case, the larger the metallic surface area in contact with the earth, the better the system ground. Multiple ground rods as well as ground screens (e.g., $\frac{1}{2}$" wire mesh) buried under the earth are not to be overlooked!

The theoretical patterns of a terminated Beverage are of interest in approximating its performance in the field. Although the discussion here is restricted to the antenna in free space (i.e., infinitely remote from a ground plane) when computing patterns, the patterns so obtained can be used with the ground plane present by accounting for certain "most likely" pattern perturbations such as elevated vertical directivity. The equation for such a terminated Beverage is given below under the assumption of a simple current distribution along the wire when the antenna is in the active (transmitting) mode and then appealing to the Reciprocity Theorem for the passive (receiving) case. It is of some musing interest to note that almost all antenna work by electromagnetic-mathematicians resort to this type of analysis. (GPN on loops has done the more difficult problem of passive analysis and his work is quite exceptional in the field of electromagnetics!)

$$E = K\left(\frac{\sin(\psi)}{1-\cos(\psi)}\right)\sqrt{1-\cos\ L^{\circ}\left[(1-\cos(\psi))\right]} \quad \text{mv/m @ M miles}$$

where K is a constant depending on parameters of little interest here, ψ is the angle measured from the wire as in Figure B and L° is the length of the wire in wavelengths at the frequency of operation, viz: $L^{\circ} = 360\, f\, L\, /\, 984 \doteq 0.366 fL$

where f is the frequency in mHz and L is the antenna length in feet. Since the interest here is in the relative performance of these antennas for different lengths L at various BCB frequencies f, the only factor of interest in the above equation is:

$$A = \frac{1}{C}\left(\frac{\sin(\psi)}{1-\cos(\psi)}\right)\sqrt{1-\cos\left[L^{\circ}\,(1-\cos(\psi))\right]}$$

where the factor (1/C) has been added to normalize the patterns with respect to a specific chosen pattern for the purpose of comparative analysis. It is suggested that for the shortest length L and the lowest frequency f, that C = 1 for the calculation of this "initial" pattern. Then in this "initial" pattern find the maximum value of A, say AM, and set C equal to this value. Then divide all values of this "initial" pattern by C so that its maximum value is now 1.0. For all subsequent patterns, C = AM. Calculations need only be made for the range $0^{\circ} \leq \psi \leq 180^{\circ}$ since the patterns are symmetrical about the axis of the antenna wire.

An antenna pattern is inherently three-dimensional! In almost all pattern plots (save for the stereographic projections, for example) a plane is passed through the pattern and contours (pattern projections) are then plotted in that plane. The usual planes are the "horizontal" and "vertical" planes sometimes measured with respect to the earth, sometimes the antenna or whatever else is handy. Figures D and E show this procedure for a loop antenna. The three dimensional pattern of an electrically small perfect loop is a "donut" with a pinhole center. Figure D is that pattern traced on the plane passing through the plane of the loop and Figure E is that traced on the plane normal or perpendicular to the loop--the apex pattern BCB DXers strive for! The terminated Beverage has a pattern symmetrical about the antenna wire as shown in Figure F. The three dimensional pattern is that envisioned by rotating or revolving the plotted pattern about the wire axis to form "cones" of radiation/reception about the antenna.

Beverage antennas in practice actually do not assume their characteristics until the length of the wire becomes significant with respect to wavelength--even tho patterns can be calculated for any length. For this discussion we shall restrict our attention to L° = 0.5 to L° = 4.0 wavelengths. The wavelength W in feet for any frequency given in mHz is computed from W = 984/f. Thus, one wavelength at 540 kHz is 1822 feet while one wavelength at 1600 kHz equals 615 feet. Table II gives W in feet as a function of f and L°. A few comments can be made about Beverage patterns in general. There is a lobe (peak) for every half-wave length in the wire and if the number of half-wavelengths is odd, then there will be a lobe at ψ = 90°, i.e., at right angles to the antenna. There is only one major lobe (shown as two such lobes in a planar projection) and this lobe tends to "fold" toward the wire axis as the length of the antenna is increased. The length of the wire for the lobe to fall within 10-15° of the wire axis is much too long for any practical consideration here. When L° = 7.0, the major lobe has its maximum at 19°. Also it is clear when observing the patterns that as the wire length increases with respect to wavelength, the number of lobes increase and their corresponding widths decrease.

Reviewing Patterns I-VIII, hand drawn from computer evaluation of the above equation for A with ψ ranging 0-180° in 1° increments, which show estimated practical performance in the horizontal plane with ground, one must remember that the pattern of the antenna changes with frequency so that as one tunes across the BCB the "big eye" keeps changing its view. For example, an 1800' Beverage assumes the basic pattern of Pattern II at 540 kHz and as one tunes toward 1600 kHz, the pattern continuously varies from Pattern II to Pattern VI. Note that the patterns plotted are taken in half-wave increments (solely for convenience here) and only 0-180° of each pattern is drawn. Also note that Mother Nature's Fundament: "You Can't Have Your Cake and Eat it Too" holds: viz., as the major lobe becomes more directive, so the number of side and back lobes increase! Thus, although the Beverage has tremendous "forward" gain compared to the side and back lobes (even more so when compared with a loop!!!) these minor lobes are significant when compared with, say a loop, so that one should not expect "super" suppression thereabouts. The usual BCB pests and dominants still show but stations coming in off the main lobes may well override them--they therefore do not retain their status as dominants and pests in many cases! Also note that a pattern such as Pattern II may, in practice, perform better than one such as Pattern VIII because the sidelobes are not as numerous thus allowing suppression over wider areas or arcs of azimuth although the major lobes differ significantly.

The size of the wire used IS important in the sense that the larger the wire diameter, the smaller the RF resistance per unit length. RF resistance represents energy loss in the system and destroys the patterns by reducing the null depths significantly between lobes as well as distorting lobes, especially the major one--Figure H. The longer the wire the greater the RF resistance so once again Mother Nature strikes: you obtain significant increase in forward or main lobe gain/directivity at the expense of getting more side and back lobes and increased RF resistance tending to "smear" the entire "tailend" together thus allowing much BCB to leak in on the sides and back. Too, the larger the wire diameter, the more resistant the antenna is to wire breakage. For those interesting in approximating the RF loss resistance, the following formula is applicable to copper wire: $RL = 1.02\ (L/D)\sqrt{f}\ /1000$ ...ohms, where, as before, L is the antenna length in feet, D is wire diameter in inches and f is frequency in mHz. For example, a 3200' Beverage made of 24GA copper has an RF resistance, RL, equal to 162 ohms at 1000 kHz while the same antenna made of 18GA copper has RL = 81 ohms at 1000 kHz. A measure of the RF efficiency of this antenna can be made from the following formula: $Eff = (100R)/(R + RL)$ ...%. With R = 560 ohms, for example, and the 3200' Beverage above using 24GA, we have Eff = 76% while the same antenna using 18GA renders Eff = 87%. Power loss is directly proportional to the RF resistance.

Table III lists some useful statistics. L° denotes the length of the antenna in wavelengths, ψ* denotes the azimuth angle at which a lobe maximum occurs, E* is the magnitude of such a lobe referenced to the maximum lobe for L° = 1.0 thus giving a comparison of these antennas as their length is increased, dB* is the corresponding power gain of such a lobe, again referenced to the maximum lobe of L° = 1.0 and dBL is the amount of "suppression" the sidelobes (for fixed L°) have with respect to the major lobe for that specific pattern. Table III lists these parameters for L° = 0.5 to L° = 7.0 in increments of 0.5 wavelengths. More comments can now be made. Note, too, that if L is a multiple of an even number of half-wavelengths, then there is a null at ψ = 90°. The angular compression of the lobes is clearly shown. The separations between lobes at L° = 2.0 are 39°, 29°, and 32° while for L° = 7.0, they are 19°, 12°, 10°, 9°, 9°, 8°, 8°, 8°, 9°, 9°, 10°, 11°, and 15°, thus showing the "clutter" of lobes for large L°. The size of these sidelobes for large L° is also significant, e.g., for L° = 7.0 @ * = 86°, E* = 0.55343 or more than one-half the major lobe of L° = 1.0. Thus, "bigger" is not necessarily "better"!

Finally, an essential point in presenting this writing is to give the BCB DXer knowledge of the general behavior of a terminated Beverage so that he can erect such an antenna attempting to orient it in such a way as to optimize its use for his purposes--e.g., aligning the "pests" and "dominants" as close as possible to the completed null areas with the understanding however that the "powerhouses" aren't likely to be "wiped out" but they can be "knocked down" considerably. The essential point to remember is that the arguments given here are an approximation to actual field performance and that Figure H should always be kept in mind!! Figure G is also important to remember because the pattern of the Beverage is three-dimensional and a "cone" about the wire axis so that reception directly "off the end" of the Beverage is to be expected though the horizontal pattern plots show no response there! --de Fish, Ph. Dx

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Project NEBE (NEbraska BEverage) was started in October 1972 here in Nebraska with the blessing of the University of Nebraska and is carried on solely for the analysis of the Beverage on the BCB! It will eventually involve analysis of TA/TP paths through the polar cap/ring. One square mile of land is dedicated for this single project for an indefinite period of time. Numerous Beverage antennas will be constructed and evaluated under my direction and the results will be given to the BCB fraternity with the hope that it will be of pragmatic value for other "in-the-field" BCB DXpeditions. The initial phase of Project NEBE has been completed and the results will be given to the DX bulletins in the very near future as a sequel to this writing. Good DXing!!!

See Tables I (Terminating Resistances), II (Wavelength vs. Frequency), and III (Pattern Comparisons); also Figures A through H; and Patterns I, II, III, and IV for L° = 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, and 4.0.

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Table I --- Terminating Resistance R

	H(feet) -------	5	8	10	15	20	25
Wire Size	D(inches)			--R ohms--			
24	0.02010	562	591	604	626	645	659
22	0.02535	548	576	590	614	631	645
20	0.03196	534	563	576	600	617	631
18	0.04030	520	549	562	586	604	617
16	0.05062	507	535	548	572	590	603
14	0.06408	493	521	534	558	576	589
12	0.08081	479	507	520	545	562	575
10	0.10190	465	493	506	531	548	561

Table II --- Wavelength vs. Frequency (table values in feet)

f \ L° =	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0
540kHz	911	1622	2733	3644	4555	5467	6378	7289	8200	9111	10022	10933	11844	12755
1600kHz	308	615	923	1230	1538	1845	2153	2460	2768	3075	3383	3690	3998	4305

Beverage Antenna Patterns for

L° from 0.5 to 7.0 wavelengths

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Table III --- Pattern Comparisons

L°	φ*	E*	dB*	EL*	dBL
0.5	65	0.638	-3.9	1.0	0.0
1.0	48	1.000	0.0	1.0	0.0
1.0	113	0.322	-9.8	0.322	-9.8
1.5	40	1.266	2.1	1.0	0.0
1.5	67	0.526	-5.6	0.417	-7.6
1.5	127	0.246	-12.2	0.194	-14.3
2.0	35	1.486	3.4	1.0	0.0
2.0	74	0.676	-3.4	0.455	-6.8
2.0	103	0.406	-7.8	0.273	-11.3
2.0	135	0.206	-13.7	0.139	-17.1
2.5	31	1.678	4.5	1.0	0.0
2.5	65	0.798	-1.9	0.476	-6.5
2.5	89	0.521	-5.7	0.310	-10.1
2.5	113	0.341	-9.3	0.203	-13.8
2.5	140	0.181	-14.8	0.108	-19.3
3.0	26	1.849	5.3	1.0	0.0
3.0	56	0.824	-1.7	0.446	-7.0
3.0	80	0.614	-4.2	0.332	-9.6
3.0	99	0.439	-7.1	0.237	-12.5
3.0	119	0.301	-10.4	0.163	-15.7
3.0	143	0.163	-15.7	0.088	-21.1
3.5	26	2.006	6.0	1.0	0.0
3.5	54	0.997	-0.1	0.497	-6.1
3.5	73	0.696	-3.1	0.347	-9.2
3.5	90	0.516	-5.7	0.257	-11.8
3.5	106	0.387	-8.3	0.193	-14.3
3.5	124	0.272	-11.3	0.136	-17.4
3.5	146	0.150	-16.5	0.075	-22.5
4.0	25	2.151	6.6	1.0	0.0
4.0	51	1.081	0.7	0.502	-6.0
4.0	68	2.096	-2.3	0.356	-9.0
4.0	82	0.585	-4.7	0.272	-11.3
4.0	97	0.456	-6.8	0.212	-13.5
4.0	112	0.348	-9.2	0.162	-15.8
4.0	128	0.250	-12.0	0.116	-18.7
4.0	148	0.140	-17.1	0.065	-23.7
4.5	23	2.289	7.2	1.0	0.0
4.5	47	1.160	1.3	0.507	-5.9
4.5	63	0.835	-1.6	0.365	-8.8
4.5	77	0.649	-3.8	0.283	-10.9
4.5	90	0.516	-5.7	0.226	-12.9
4.5	103	0.410	-7.7	0.179	-14.9
4.5	116	0.322	-9.8	0.140	-17.0
4.5	131	0.233	-12.7	0.102	-19.8
4.5	150	0.131	-17.6	0.057	-24.8
5.0	22	2.418	7.7	1.0	0.0
5.0	45	1.239	1.9	0.512	-5.8
5.0	60	0.894	-1.0	0.370	-6.6
5.0	72	0.704	-3.1	0.291	-10.7
5.0	84	0.572	-4.8	0.237	-12.5
5.0	96	0.464	-6.7	0.192	-14.3
5.0	107	0.379	-8.4	0.157	-16.1
5.0	120	0.298	-10.5	0.123	-18.2
5.0	134	0.218	-13.2	0.090	-20.9
5.0	152	0.124	-18.1	0.051	-25.8
5.5	21	2.541	8.1	1.0	0.0
5.5	43	1.307	2.3	0.515	-5.8
5.5	57	0.951	-0.4	0.374	-8.5
5.5	66	0.752	-2.5	0.296	-10.6
5.5	79	0.619	-4.2	0.244	-12.3
5.5	90	0.516	-5.7	0.203	-13.8
5.5	100	0.429	-7.4	0.169	-15.4
5.5	111	0.353	-9.0	0.139	-17.1
5.5	123	0.280	-11.0	0.110	-19.1
5.5	136	0.207	-13.7	0.081	-21.8
5.5	153	0.118	-18.6	0.046	-26.7
6.0	20	2.660	8.5	1.0	0.0
6.0	41	1.376	2.8	0.517	-5.7
6.0	54	1.009	1.8	0.380	-6.4
6.0	66	0.781	-2.1	0.294	-10.6
6.0	75	0.664	-3.6	0.250	-12.0
6.0	85	0.562	-5.0	0.211	-13.5
6.0	95	0.472	-6.5	0.178	-15.0
6.0	104	0.399	-7.9	0.150	-16.5
6.0	114	0.330	-9.6	0.124	-18.1
6.0	125	0.264	-11.6	0.099	-20.0
6.0	138	0.196	-14.1	0.074	-22.6
6.0	154	0.113	-18.9	0.042	-27.5
6.5	19	2.770	8.8	1.0	0.0
6.5	39	1.439	3.2	0.520	-5.7
6.5	52	1.059	0.5	0.383	-8.3
6.5	62	0.848	-1.4	0.306	-10.3
6.5	72	0.710	-3.0	0.257	-11.8
6.5	81	0.604	-4.4	0.218	-13.2
6.5	90	0.516	-5.7	0.186	-14.6
6.5	99	0.440	-7.1	0.159	-15.9
6.5	108	0.375	-8.5	0.136	-17.4
6.5	117	0.312	-10.1	0.113	-18.9
6.5	128	0.252	-12.0	0.091	-20.8
6.5	140	0.188	-14.5	0.068	-23.4
6.5	155	0.108	-19.3	0.039	-28.2
7.0	19	2.674	9.2	1.0	0.0
7.0	38	1.498	3.5	0.521	-5.7
7.0	50	1.107	0.9	0.385	-8.2
7.0	60	0.895	-0.9	0.311	-10.1
7.0	69	0.751	-2.5	0.261	-11.7
7.0	78	0.631	-4.0	0.220	-13.2
7.0	86	0.533	-5.1	0.192	-14.3
7.0	94	0.481	-6.3	0.167	-15.3
7.0	102	0.414	-7.6	0.144	-16.8
7.0	111	0.354	-9.0	0.123	-18.1
7.0	120	0.298	-10.0	0.104	-19.7
7.0	130	0.241	-12.4	0.084	-21.5
7.0	141	0.179	-14.9	0.062	-24.0
7.0	156	0.164	-19.7	0.036	-28.8

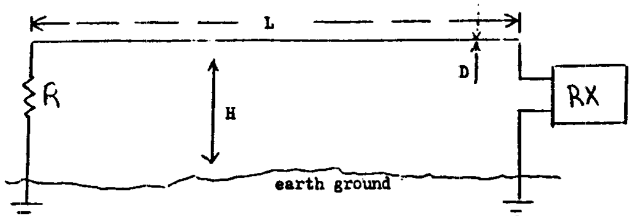

Figure A: Side View of Antenna

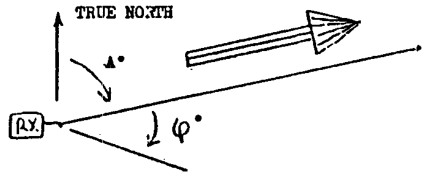

Figure B: Top View of Antenna

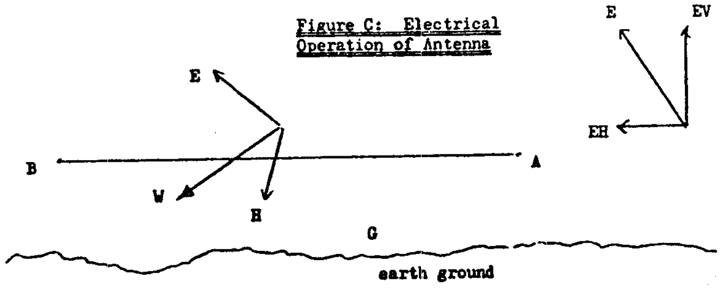

Figure C: Electrical Operation of Antenna

Figure D: Loop Pattern

Plane of Loop

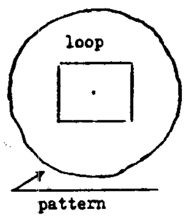

Figure E: Loop Pattern

Normal Loop Plane

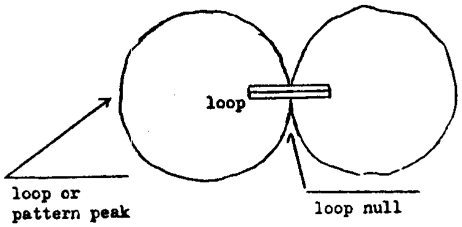

Figure F: Typical Terminated Beverage Pattern

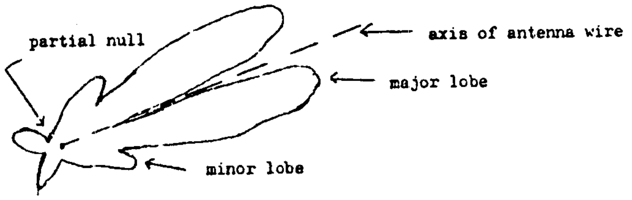

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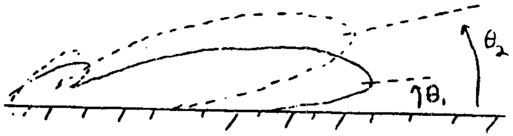
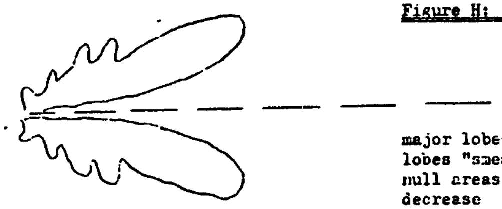
Figure G: Effects of Ground Plane on Vertical Pattern



ground plane
"elevates" pattern
in vertical plane

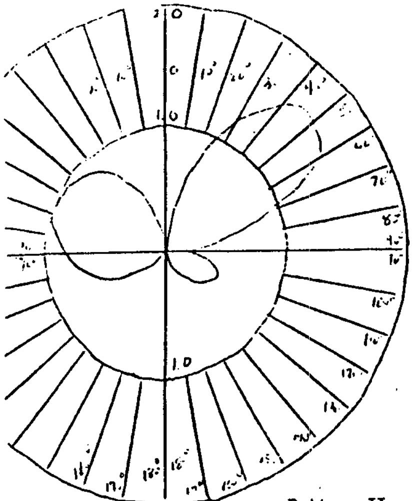
earth ground plane

Figure H: Pattern Distortion due to RF Resistance



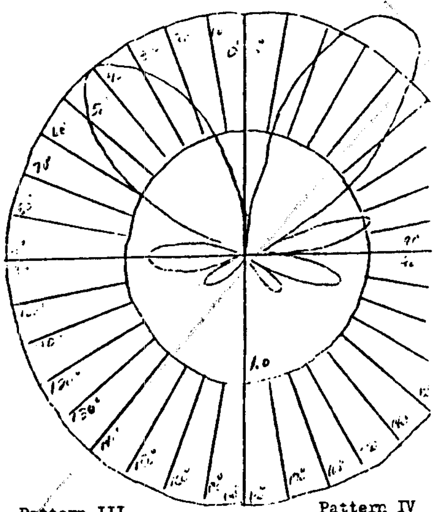
axis of antenna wire

major lobes are distorted and minor lobes "smear" together diminishing null areas, size of lobes also decrease



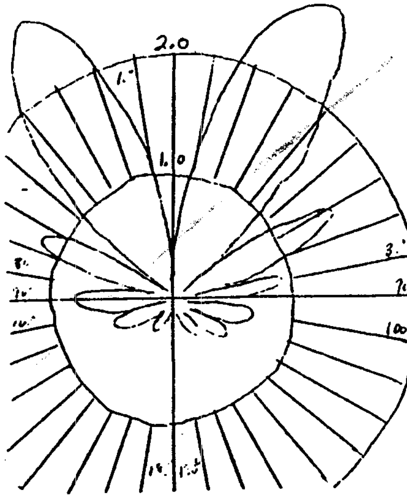
Pattern I
L° = 0.5

Pattern II
L° = 1.0



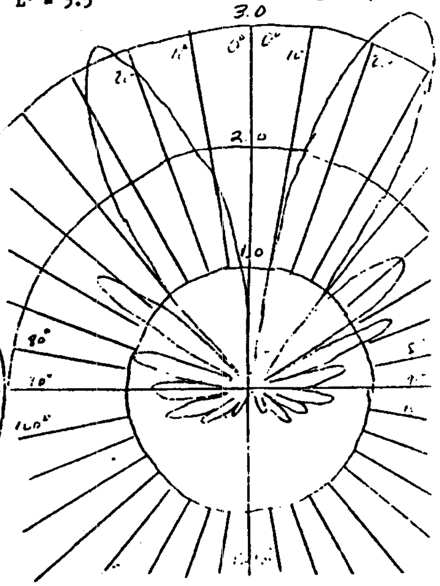
Pattern III
L° = 1.5

Pattern IV
L° = 2.0



Pattern V
L° = 2.5

Pattern VI
L° = 3.0



Pattern VII
L° = 3.5

Pattern VIII
L° = 4.0