SUMMARY OF EXPERIMENTS WITH THE SEPARATED APERTURE TECHNIQUE OF DIELECTRIC ANOMALY DETECTION

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SUMMARY OF EXPERIMENTS WITH THE SEPARATED APERTURE TECHNIQUE OF DIELECTRIC ANOMALY DETECTION

1. INTRODUCTION

This report summarizes experiments conducted from early 1972 through 1979 by the National Institute of Standards and Technology (formerly NBS) for what was ~~then~~ the Mine Detection Division, Counter-Mine, Counter-Intrusion Department, U.S. Army Mobility Equipment Research and Development Center. The objective of this report is to provide a condensed overview of the major things tried, with an indication of how well they worked, and a reference to the original report that will allow finding the more detailed description if desired. The summary is based primarily on the quarterly progress reports and secondarily, because it has not been possible to locate copies of all the reports, on the recollections of the author and others who did the work.

The objective of the experiments was to study and improve what has generally been called the separated aperture system of dielectric anomaly detection. The detection portion of the system is a "head" made of a transmit antenna and a receive antenna separated by a flat plate called the "septum". See Appendix A for sketches of many of the heads and array configurations tested. The work was started with two initial head designs which were continually modified in the effort to improve performance.

While the items tested were primarily the different versions of the separated aperture heads, a small number of other antennas was also evaluated. These included broadband horns used for time domain measurements, a narrow band horn used for holographic imaging, and cross polarized antennas that were used in an antipersonnel mine detector.

The majority of the experiments was conducted in Boulder, Colorado at the NIST field site. Measurements were also made at sites in Butte, MT, Ft Belvoir, VA, and at a second site near Boulder. The NIST field site was initially very rocky. In three fourths of the test area the soil and rocks were removed to a depth of 6 feet and replaced with screened soil; the remaining quarter of the site was left as it was. A section of the rock-free area was covered with a shed to allow the moisture content to be controlled and to allow work to continue throughout the year. The site, with the three distinct test areas, is shown in Figure 1-1.

The primary measurement instrument was an HP8542 automatic microwave network analyzer mounted in a van. The van was fitted with heating and air conditioning to provide a reasonable environment for the computer operated system. In the field, AC power was provided by a 12.5 KVA generator mounted on a trailer, and a 6 KVA unit in the van. The test antennas were generally mounted beneath a computer controlled cart which was moved by stepping motors. The cart was guided by a single rail so the measurement path (X axis) could be accurately repeated. The height (Z axis) of the antenna was also remotely controlled. A swinging boom fastened to the van roof supported the control and measurement cables. The coax measurement cables were chosen to obtain minimum phase shift with cable flexing. The electrical length also changes with temperature; in some critical measurements it was found helpful to wrap the cable with additional foam insulation and aluminum foil. Cable loss was compensated by a gain stable microwave amplifier on the network analyzer input port.

A database containing report references and a brief description of the purpose, measurement conditions, and results, for many of the experiments is included as Appendix B. This listing should be useful in giving additional information or locating the original report of an experiment.

In most of the reports, the performance comparisons are based on the plot of a processing algorithm called the Target Amplitude Descriptor (TAD). The algorithm is essentially an average over frequency of the target-to-background ratio. It makes objective comparisons possible by providing a way to describe the head response over each target by a single number. Other data presentations in the reports include three-dimensional projections (response amplitude vs. frequency vs. position), and single frequency amplitude vs. position plots. For a detailed description of TAD, see Appendix C.

Other forms of data display were also used. A 2-D contour plot showing the response amplitude as a function of X and Y position at a single frequency and height was very useful in analyzing target coverage capability. A 3-D plot showing response amplitude as a function of X position and frequency for a single height and offset (Y position) was important in determining the overall frequency response of a head. It would also show any frequency dependent features in the response.

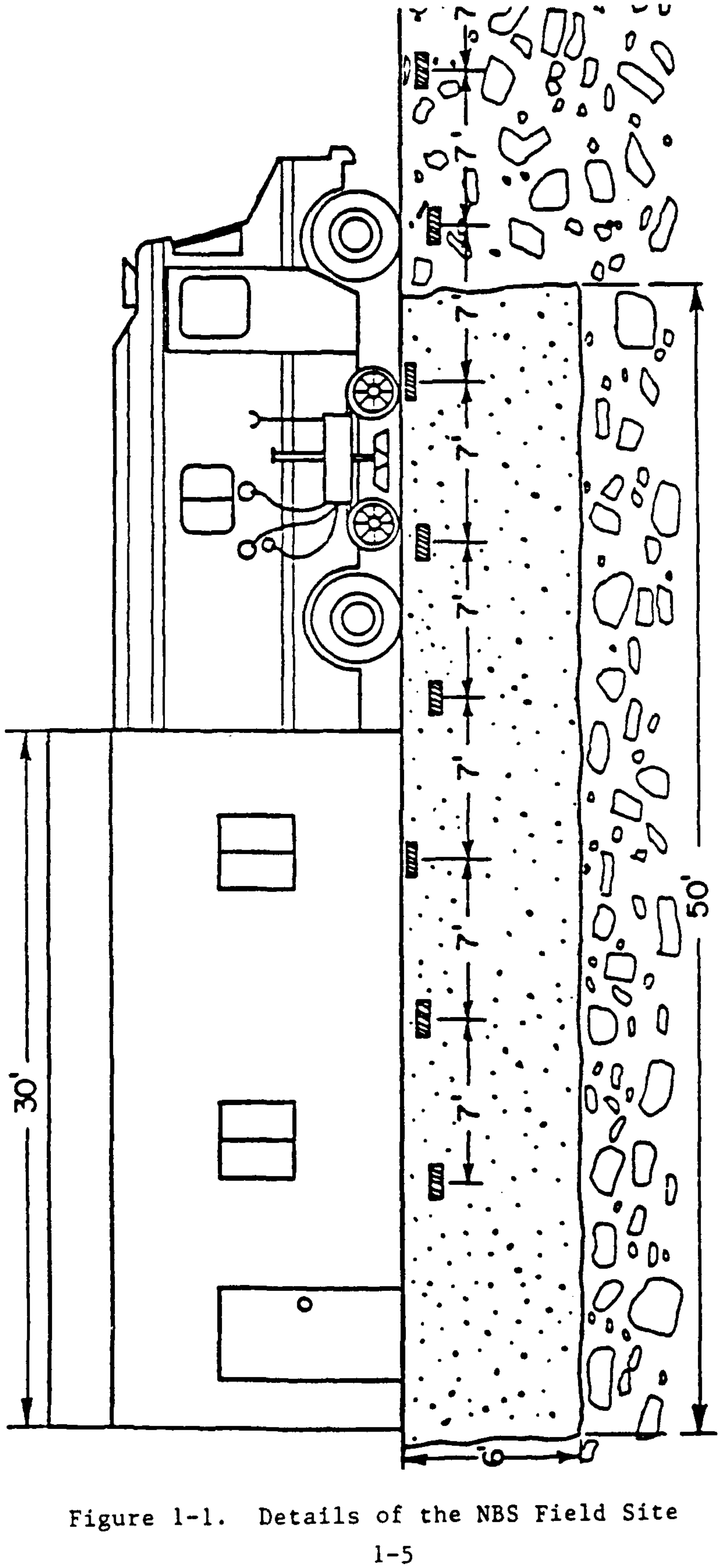

Figure 1-1. Details of the NBS Field Site

2. EXPERIMENTS

Before describing the experiments, the head-identifying abbreviations need to be explained. The naming convention is based on the operating frequency and reflector shape. The initial number is the center operating frequency for the head, usually expressed in MHz unless otherwise noted in the name (ie. the 1 GHz SYH). The remaining letters refer to the general shape of the reflector; "NSYH" indicates a nonsymmetrical reflector using printed circuit dipoles as typified by the 790 NSYH, and "SYH" means a symmetrical reflector with adjustable tubular dipoles as typified by the 790 SYH.

The discussion of the measurements and results is divided according to the different performance parameters that were investigated. The major comparison parameters are: the head height, the target type and depth, the soil moisture content, and head and array coverage. Other factors were investigated, and some of these are included with the major ones in the reference listing in Table 2-1. This table gives experiment reference numbers (which identify the individual experiment or series as listed in Appendix B) for a particular performance factor and the tested head configurations.

The performance items will be described and discussed in the order they are listed in Table 2-1. The conclusions given are based on the overall results of most of the experiments, although there were occasional test results that would contradict these general observations. Summaries for each head are presented in the next section.

A. HEAD HEIGHT

For most of the experiments at least three heights were run; the exact values were dependent on the head. For the 790 heads, 1, 3, and 5 inches were most often used, with 3 inches typical for an experiment run at a single height.

As might be expected, it was found that the lower frequency heads could successfully operate at a higher height. The 450 NSYH was usable to 5 inches, while the 1 GHz SYH was limited to below 3 inches.

B. TARGET TYPE AND DEPTH

The targets were generally mockups of antitank mines. They were made by filling a real mine case with a material such as paraffin whose dielectric properties are similar to TNT. The mine types used in the experiments were: the TMDB, M19, PM-60, and an antipersonnel mine, the PMN-6. In a few cases, other shapes and sizes of dielectric objects were used, as well as a metal culvert and voids.

The targets were most often laid out in a row at different depths as indicated in Figure 1-1. Some of the series of depths used were (in inches): 2,6,9; 1,2,4; 2,4,6,12; 1,3,5; 0.5,1. The test lane was usually an unimproved dirt track, but an oiled gravel road was used in one case, and asphalt pavement in a another test. (No head was able to detect the target beneath asphalt.)

The ability of the heads to detect the targets at different depths was to a large extent dependent on the soil moisture content and the operating frequency of the head.

C. SOIL MOISTURE CONTENT

Moisture content was determined at least once a day. The sample was generally taken from the side of the field at a depth of about 4 to 6 inches, which gives only an indication of the moisture content near the targets. At times the samples were taken near the target and at the same depth for a more accurate value. The measurement was made using a commercial device called the "Speedee Moisture Meter".

It should also be noted that the moisture content at saturation can vary widely depending on the soil composition. A moisture content of 14% would represent near saturation for the NIST site soil, while it would represent only a moderately damp soil for the heavy clay found at the Ft. Belvoir field site.

D. DIFFERENT SEPTUM WIDTHS

Part of the process to improve the heads that looked most promising included a series of experiments to determine the optimum septum width. It was found that the best width for any given head was dependent on the soil moisture content, target depth, and antenna height. As a general observation, the septum width needs to increase with dry soil, target depth, and antenna height.

Thus, the septum width used with any particular head is a compromise.

E. COVERAGE WITH SINGLE HEAD OFFSET

This refers to experiments to determine how far to the side of a target (off center) a head could be run and still detect it. The maximum offset turned out to be a function of many things: soil moisture, target deptn, head height, reflector size and shape, head orientation, and operating frequency. The 790 SYH and 890 NSYH (the smaller heads) were found to be the best in these tests.

F. COVERAGE WITH MULTIPLE HEAD ARRAYS

A large number of tests were run with different array configurations. The arrays primarily consisted of one or the other of the 790 heads. The 790 NSYH arrays were mostly made up of separate heads side-by-side, run in the 0 degree orientation. (The 0 degree orientation is with the head parallel to and the dipoles perpendicular to the direction of travel. The 90 degree orientation is with the dipoles parallel to the direction of travel.) The 790 SYH arrays were made of side-by-side reflectors run in the 90 degree orientation.

The arrays were also tested in articulated configurations (which allow the individual heads to each follow the terrain contour). For the nonsymmetrical arrays, the separate heads were run at different heights. For the symmetrical arrays, split septums were tested and found to be a usable way to let the individual array reflectors operate at different heights and thus follow the terrain. The best coverage was obtained by using two staggered rows of 790 symmetrical heads.

G. DIFFERENT DIPOLES

These were tests of the different heads with other forms of dipoles than those originally used. It was found that the tubular dipoles did not work well in the nonsymmetrical heads, that broadband dipoles such as the bow-tie did not retain their bandwidth when placed in the reflectors, and, not surprisingly, dipoles tuned for one frequency did not work well when placed in a reflector with a size optimum for another frequency.

H. FALSE ALARMS OR ROCKS

A false alarm is a head response greater than the threshold set for targets. Rocky soil generally did not appear to cause false alarms, while existing holes that were refilled, even if well packed, often did. When one head would show a false alarm, other heads being tested at the same time would not necessarily respond the same way. In the tests, there were actually very few false alarms seen, a positive attribute of the separated aperture technique.

I. MODE BLOCKS AND FILTERS

These were tests to determine the leakage modes and what path the energy takes in propagating between the transmit and receive dipoles when over a target. The leakage was found to be a TE mode that propagates between the ground surface and the septum. The mode block experiment indicates that the detection mode is largely transmitted in the soil over the target, which seems to explain why the low frequency heads could not detect shallow targets, especially in dry soil. Probes placed within a target indicated some energy there, with the strongest field component horizontal, parallel to the dipoles.

J. HARDENED HEADS WITH DIELECTRIC FILL

These were tests to determine the effect of the "hardening" necessary to allow the heads to be used under field conditions. The heads were filled with polyurethane foam and covered with a 1/16" fiberglass cover. This was done to the 790 NSYH and the 790 SYH. There was little change in either head, except for a slight improvement in coverage for the 790 SYH. Other tests were done with a 790 SYH head filled with material of much higher dielectric constant in an attempt to decrease the size of the head for improved coverage. There was a coverage improvement, but the additional microwave loss decreased the response along with the operating height, and the weight was excessive.

K. ANTIPERSONNEL MINES

Toward the end of the project, work was done to develop and test a hand-held high frequency head for detecting small antipersonnel mines. It was moderately successful, but did have several problems, such as giving a false alarm with an abrupt height change. In spite of the problems, it was the first head that would even respond at all to such small and shallow targets. More detailed information about the head is presented in the next section.

L. MISCELLANEOUS

A number of other experiments and measurements were performed. They were of short duration, and somewhat peripheral to the main work with the separated aperture. They included obtaining data with an S band horn for another MERDC contractor to use in holographic imaging, trying broadband horns with separated aperture and time domain methods, development of techniques and instruments for soil dielectric constant measurements, and measurements on cross-polarized antennas. Some of these measurements are included in the listing found in Appendix B.

As noted in the introduction, some of the reports are missing, and details of the experiments are not available. One of these tests was to extend the frequency range much lower than normal for one the symmetrical heads (probably the 790 SYH). The sensitivity was also increased with an additional amplifier. It was found that the response continued below what had been thought was the low frequency limit, and in fact, the signal to background ratio actually increased over what it was at the peak response point. Since generally the best performing head was the one with the greatest bandwidth, this was an important finding. It came late in the program and was not further investigated.

HEAD CONFIGURATION	450 NSYH	550 SYH	670 NSYH	790 NSYH	790 SYH	890 NSYH	900 SYH	1 GHz SYH	1.2 GHz SYH
PERFORMANCE: WITH HEAD HEIGHT CHANGE	12	5,6	1,3,7,9, 10,13	4,8,11,14,28, 30,34,37,42, 57,67	29,31,38,41, 47,56,59,66, 69,74,75	39,43,	60,65,70	40,61,64, 68,72	73
WITH TARGET TYPE AND/OR DEPTH	12,19	5,6,23, 24,26,27, 36	3,7,9,18, 20,22,25	4,8,11,14,16, 17,21,28,30, 34,37,42,45, 54,57,63,67	29,31,35,38, 41,44,46,47, 48,49,50,51, 52,53,55,56, 57,59,62,66, 69,74,75	39,43	60,65,70	40,61,64, 68,72	73
WITH SOIL MOISTURE CHANGE	12,19	23	9	11,17,28,30, 34,37,42,63, 67	29,31,38,41, 66,69,74,75	39,43	65	40,64,68, 72	73
WITH DIFFERENT SEPTUM WIDTH				11,34,67	62,66,69		65,70	64,68,72	73
COVERAGE (WITH SINGLE HEAD OFFSET)		36		37,42	35,38,48,49, 50,51,52,59	39,43		40	
COVERAGE (WITH ARRAY CONFIGURATIONS)			13,15	14,16,45,54	35,41,44,46, 47,53,55,62				
WITH DIFFERENT DIPOLES		24	20,22,25	21	74,75				
FALSE ALARMS OR ROCKS	19		18	17,42	41	43			
WITH MODE FILTER		26,27							
WITH HARDENED HEAD OR DIELECTRIC FILL				57	56,59				
WITH ANTIPERSONNEL MINE							60	61,72	73

TABLE 2-1. EXPERIMENT REFERENCE NUMBERS FOR A PARTICULAR HEAD AND TESTED PERFORMANCE PARAMETER

3. HEAD PERFORMANCE

As noted in the previous section, the abbreviations identifying the heads are based on the operating frequency and reflector shape. The initial number is the center operating frequency for the head, usually expressed in MHz unless otherwise noted in the name (ie. the 1 GHz SYH). The remaining letters refer to the general shape of the reflector; "NSYH" indicates a nonsymmetrical reflector using printed circuit dipoles as typified by the 790 NSYH, and "SYH" means a symmetrical reflector usually using adjustable tubular dipoles as typified by the 790 SYH.

This section presents a summary of measurement results for each of the heads included in Table 2-1. Comments on each head and a brief description of the results in the performance areas tested for that head are shown in the form of a table.

HEAD CONFIGURATION: 450 NSYH	
COMMENTS	This was the lowest frequency head tried. It had the advantage of a greater working height than any other head. Because its large size could result in a coverage problem, and it could not detect shallow targets under wet conditions, the design was dropped. It might deserve another look, especially as a symmetrical head.
PERFORMANCE AS A FUNCTION OF:	
HEAD HEIGHT	Operating height to 5 inches and above.
TARGET DEPTH SHALLOW = 2 inches MEDIUM = 6 inches DEEP = 9 inches	Could generally detect all the targets. The head did have a problem with the shallow target in the wet condition.
SOIL MOISTURE MEDIUM = 8% WET = 10% VERY WET = 14%	In spite of what is noted above, the head generally continued to work better than the higher frequency heads as the moisture increased. Along with the other heads tested, it could not detect any targets under the very wet condition.

TABLE 3-1. GENERAL PERFORMANCE OF THE 450 NONSYMMETRICAL HEAD

HEAD CONFIGURATION: 550 SYH	
COMMENTS	Head is the same size as the 670 NSYH. Best performance turned out to be at 550 MHz. Test and development was stopped on the head after the 790 heads were judged better overall. However, under some conditions the head performed better than any other.
PERFORMANCE AS A FUNCTION OF:	
HEAD HEIGHT	As with other the other low frequency head (450 NSYH) the performance up to 4 inches and above is good - better than the higher frequency heads.
TARGET DEPTH SHALLOW = 2 inches MEDIUM = 6 inches DEEP = 9 inches	Generally responds better to the deeper targets than the shallow.
SOIL MOISTURE DRY = 5% WET = 9%	As moisture increases the shallow target is lost first. No measurements were made under very wet conditions.
COVERAGE	Does not have better coverage than 790 SYH.
MODE FILTER	Used in experiments to determine the electric field orientation in the space between the ground surface and the top of the target.

TABLE 3-2. GENERAL PERFORMANCE OF THE 550 SYMMETRICAL HEAD

HEAD CONFIGURATION: 670 NSYH	
COMMENTS	This is the original nonsymmetrical reflector using printed circuit dipoles. After the development of the 790 head, it was found to be generally inferior and was not futher developed or tested.
PERFORMANCE AS A FUNCTION OF:	
HEAD HEIGHT	Operational height was a full 5 inches.
TARGET DEPTH SHALLOW = 2 inches MEDIUM = 6 inches DEEP = 9 inches	Generally responds better to the deeper targets than the shallow. Had trouble detecting the shallow target even with medium soil moisture.
SOIL MOISTURE MEDIUM = 8% WET = 11%	Does not perform as well as the 790 NSYH run at the same time. No measurements were made under very wet conditions.
COVERAGE	A triple head with offset dipoles was tried without success.
OTHER DIPOLES	Tried bowtie, adjustable cylindrical, and 450 printed circuit dipoles. Did not materially improve the head.

TABLE 3-3. GENERAL PERFORMANCE OF THE 670 NONSYMMETRICAL HEAD

HEAD CONFIGURATION: 790 NSYH	
COMMENTS	This and the 790 SYH were the most promising and extensively tested configurations. Generally not the best nor the worst in any area, they were good on the average. In most comparisons this head was slightly to substantially inferior to the 790 SYH.
PERFORMANCE AS A FUNCTION OF:	
HEAD HEIGHT	Useful operating height was under 4 inches.
TARGET DEPTH SHALLOW = 1-2 inches MEDIUM = 4-6 inches DEEP = 9-12 inches	A very wide range of targets and depths were tested. Performance was average, except for deterioration under the wet and very wet conditions.
SOIL MOISTURE DRY = 5-8% MEDIUM = 8-12% WET = 12-14% VERY WET = >14%	Head tested under a wide range of soil moistures. At the higher moisture contents it did not perform as well as the 790 SYH.
COVERAGE	Different orientations and several array configurations with and without split septums were tried. Again, performance was inferior to the similar things done with the 790 SYH.
OTHER DIPOLES	450 printed circuit tried - no improvement. Adjustable cylindrical not tried because of negative experience with 670 NSYH.
DIELECTRIC FILL	Did not significantly affect performance.

TABLE 3-4. GENERAL PERFORMANCE OF THE 790 NONSYMMETRICAL HEAD

HEAD CONFIGURATION: 790 SYH	
COMMENTS	On the average, this head with tubular dipoles was the most promising configuration. Under dry conditions it was as good as any, and only slightly inferior under wet conditions. The symmetrical shape is key to its good coverage performance in arrays.
PERFORMANCE AS A FUNCTION OF:	
HEAD HEIGHT	Useful operating height was about 4 inches.
TARGET DEPTH SHALLOW = 1-2 inches MEDIUM = 4-6 inches DEEP = 9-12 inches	A very wide range of targets and depths were tested. Under a given situation, the performance was not always the best of the heads compared, but it was generally adequate.
SOIL MOISTURE DRY = 5-8% MEDIUM = 8-12% WET = 12-14% VERY WET = >14%	The head was tested under a wide range of soil moistures. At the higher moisture contents it continued with reasonable performance.
COVERAGE	Different orientations and several array configurations with and without split septums were tried. With two rows of heads in arrays it provided excellent coverage.
OTHER DIPOLES	The printed circuit dipoles were tried, unfortunately with negative results. The critical wet condition performance suffered significantly.
DIELECTRIC FILL	Did not significantly alter the performance.

TABLE 3-5. GENERAL PERFORMANCE OF THE 790 SYMMETRICAL HEAD

HEAD CONFIGURATION: 890 NSYH	
COMMENTS	The object of this design was to improve wet performance and coverage over the 790 NSYH. Single head coverage did improve, but at the expense of operating height. Because of that limitation, and the better performance of the symmetrical heads, the design was not further developed.
PERFORMANCE AS A FUNCTION OF:	
HEAD HEIGHT	Useful operating height was about 3 inches.
TARGET DEPTH SHALLOW =1 - 2 inches MEDIUM = 4 - 6 inches DEEP = 9 - 12 inches	Overall response was slightly inferior to the 790 heads, especially for the shallow targets.
SOIL MOISTURE DRY = 3 - 5% MEDIUM = 8% WET = 10%	The expected improvement over the 790 NSYH was not achieved. The reason for this was not clear.
COVERAGE	Coverage obtained with a single head was somewhat better than the 790 NSYH, but also, unexpectedly, much better than the 1 GHz SYH.

TABLE 3-6. GENERAL PERFORMANCE OF THE 890 NONSYMMETRICAL HEAD

HEAD CONFIGURATION: 900 SYH	
COMMENTS	This high frequency head was intended primarily as an antipersonnel mine detector. It was somewhat successful in that, but the 1 GHz SYH was better, and could operate nearly as high, so the head was not further developed.
PERFORMANCE AS A FUNCTION OF:	
HEAD HEIGHT	As with other the other high frequency heads, the operating height was very restricted, below 3 inches in this case.
TARGET DEPTH SHALLOW = 1 inches MEDIUM = 2 inches DEEP = 6 inches	Compared with the 790 heads, this head detected the shallow targets better and the deep targets worse.
SOIL MOISTURE DRY = 5% MEDIUM = 8% WET = 12% VERY WET = 14%	Was only slightly better than the 790 heads and not nearly as good as the 1 GHz SYH under the wet and very wet conditions.

TABLE 3-7. GENERAL PERFORMANCE OF THE 900 SYMMETRICAL HEAD

HEAD CONFIGURATION: 1 GHz SYH	
COMMENTS	This high frequency head was designed primarily to detect antipersonnel mines, which it did quite well. It was also found to be the best head by far for detecting full size targets under very wet conditions. The major performance limitation is the restricted operating height.
PERFORMANCE AS A FUNCTION OF:	
HEAD HEIGHT	Operating height restricted to below 3 inches, with 2 inches high the best.
TARGET DEPTH SHALLOW = 1 inches MEDIUM = 2 inches DEEP = 6 inches	Compared with the 790 heads, this head was better for detecting shallow targets, but worse for deep targets.
SOIL MOISTURE DRY = 5% MEDIUM = 8% WET = 12% VERY WET = 14%	The heads performance under very wet conditions was much better than any other head. It was even able to detect a target under 1 inch of standing water.
COVERAGE	The single head coverage was actually better than the 790 NSYH, although not as good as 790 SYH, and quite a bit inferior to the 890 NSYH.

TABLE 3-8. GENERAL PERFORMANCE OF THE 1 GHz SYMMETRICAL HEAD

HEAD CONFIGURATION: 1.2 GHz SYH	
COMMENTS	This high frequency head was designed to be used for antipersonnel mine detection. It was the most successful of any head tested for that purpose. It had performance problems with sudden changes in height, soil density, or soil moisture, which gave it a high false alarm rate. It also has a very restricted operating height.
PERFORMANCE AS A FUNCTION OF:	
HEAD HEIGHT	In comparison with the 1 GHz head, the operational height is decreased further, to below 2 inches.
TARGET DEPTH SHALLOW = 0.5 inches MEDIUM = 1 inches	The head did detect the small shallow AP targets very well. It was not tested with deep targets, but would probably not do well with those.
SOIL MOISTURE DRY = 3% MEDIUM = 7%	The head was not tested under wet or verv wet conditions.

TABLE 3-9. GENERAL PERFORMANCE OF THE 1.2 GHz SYMMETRICAL HEAD

4. CONCLUSIONS

The program conducted by NIST was primarily a pragmatic look at the separated aperture technique. The modifications tried were most often straightforward changes based on the waveguide below cut-off model[1] and the previous real-world tests. Only a few of the early measurements were directed toward a better understanding of the detection process. At the conclusion of the program, the limitations of the initial embodiment of the technique and what could be expected from it in the field were quite well understood. Unfortunately, many performance deficiencies remained. It was not a system that with a single head could detect the targets under all conditions in all places.

These deficiencies were not necessarily a basic limitation of the technique, since with different head configurations and operating frequencies the targets could be detected under many varying conditions. Detection just could not be done with a single head.

Based on the experience at NIST with the technique, the following suggested goals for future investigation and development would include:

1) Make the present head design broadband as possible. Two initial ways to increase the functional bandwidth are to use the tubular dipoles and to increase the sensitivity of the receiver.

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[1] The Detection of Dielectric Anomalies Using a Separated Aperture, James P. Montgomery, Jan 21,1973, University of Colorado technical report under subcontract to NIST. (Report previously furnished to Belvoir Research, Development, and Engineering Center.)

2) Develop "smarter" data processing schemes that could make effective use of increased head bandwidth, include phase information, and look for possible frequency dependent "signatures" to reduce false alarms.

3) Verify and explain the unique ability of the 1 GHz symmetrical head to detect the targets in very wet or even saturated soil.

4) Develop a more accurate theoretical model of the detection mechanism. This could be aided by obtaining a better knowledge of the electric field structure in the ground above the target and within the target by sampling with small, broadband probes.

5) Develop a computer model for simulation of the technique.

6) With the help of theory and simulation, develop a more efficient and broader band radiator than the present reflector/dipole.

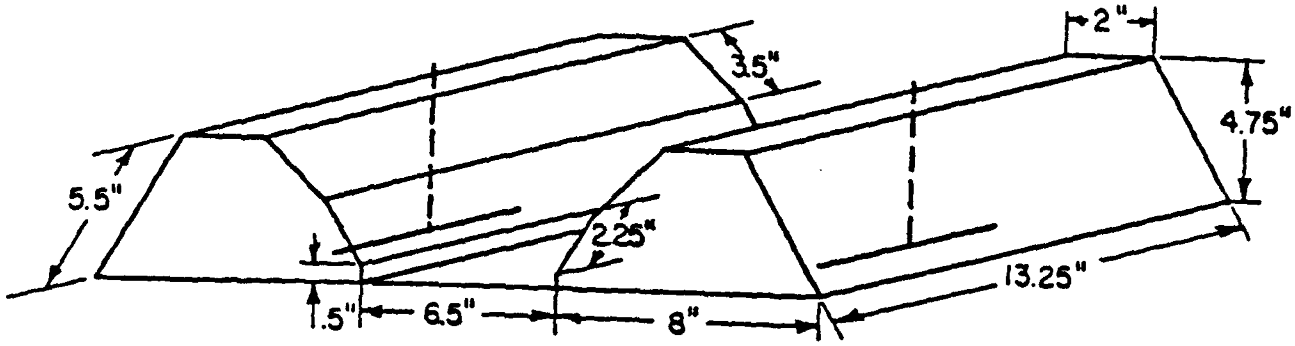
If the best performance seen in the different heads tested could be obtained at one time with a single head or with some manageable array of heads, an effective system could be put in the field. That is the major challenge for future development.

APPENDIX A. HEAD SKETCHES

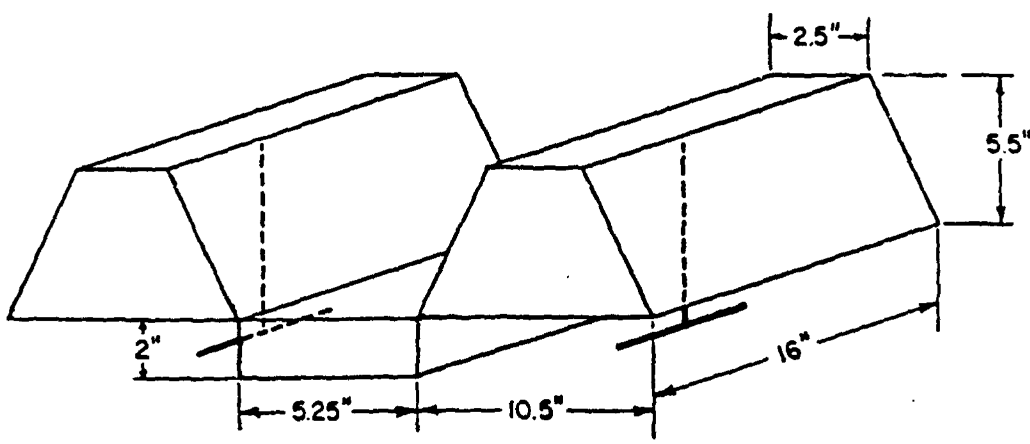
Sketches of many of the heads and array configurations used in the experiments are shown. The array configurations are often only shown as viewed from the top. The sketches are numbered so they can be referenced in the database (Appendix B). The drawings are not to scale, although in most cases some dimensions are shown. It will be noted that even though the head is named the same, the dimensions shown in the different sketches may vary. This, of course, is the result of optimizing head performance during the tests.

The first version of the head was often constructed of perforated aluminum sheet. This could be quickly cut and formed to the desired initial shape, and then easily changed as the tests proceeded.

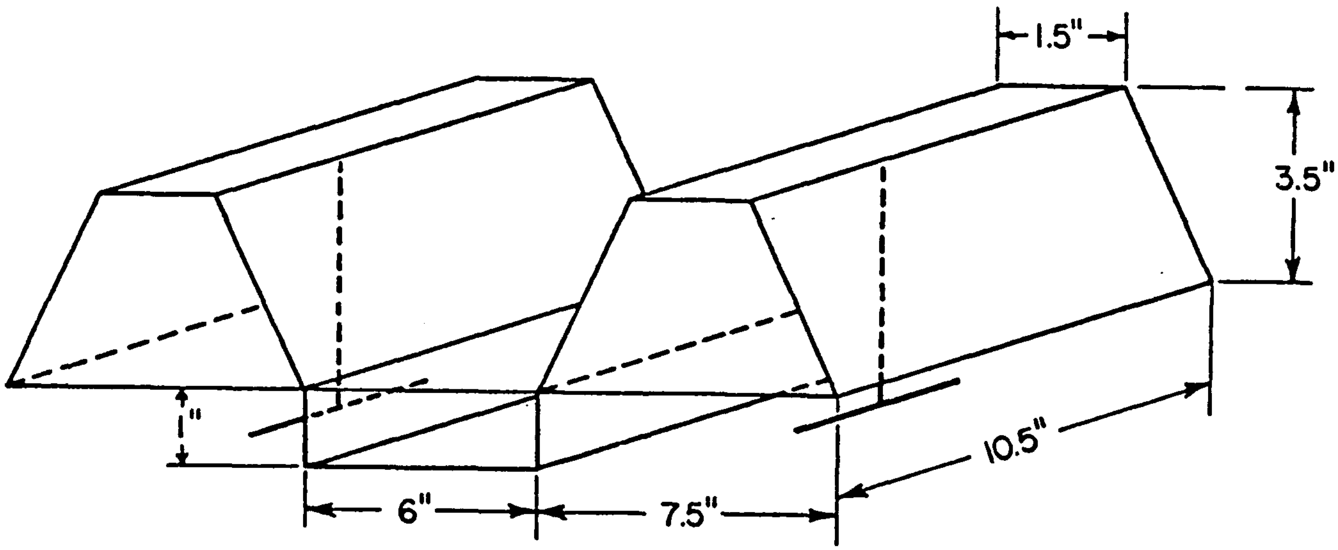
The naming convention for the heads is based on the operating frequency and reflector shape. The initial number is the center operating frequency for the head, usually expressed in MHz unless otherwise noted in the name (ie. the 1 GHz SYH). The remaining letters refer to the general shape of the reflector; "NSYH" indicates a nonsymmetrical reflector using printed circuit dipoles as typified by the 790 NSYH, and "SYH" means a symmetrical reflector usually using adjustable tubular dipoles as typified by the 790 SYH.



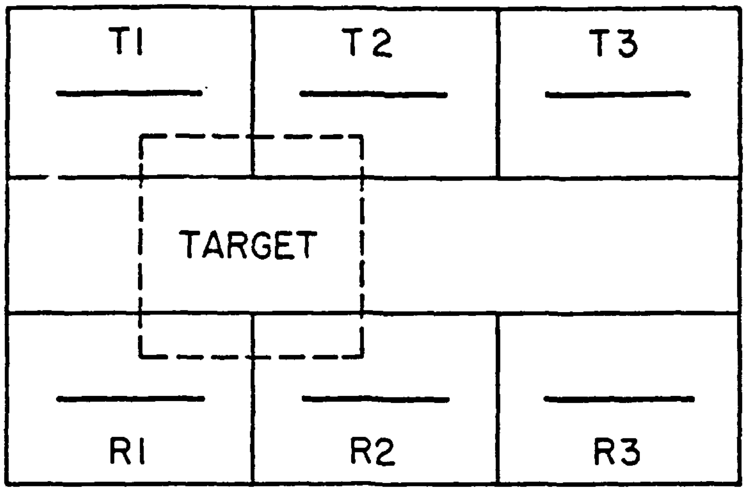
Sketch 1. 790 Nonsymmetrical Head



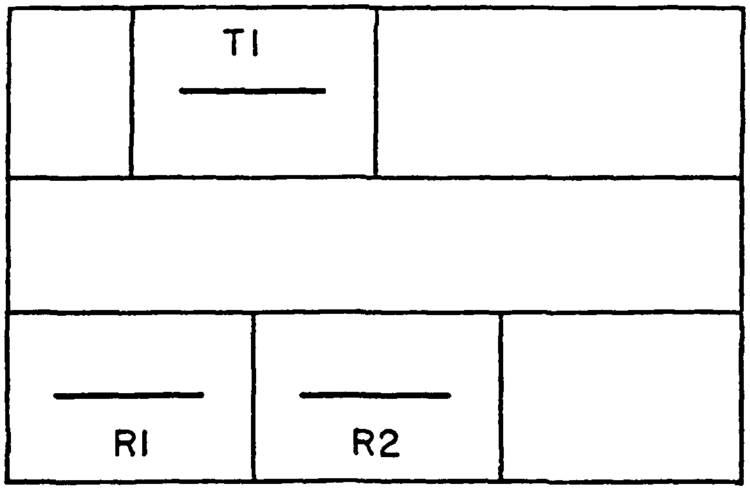
Sketch 2. 550 Symmetrical Head



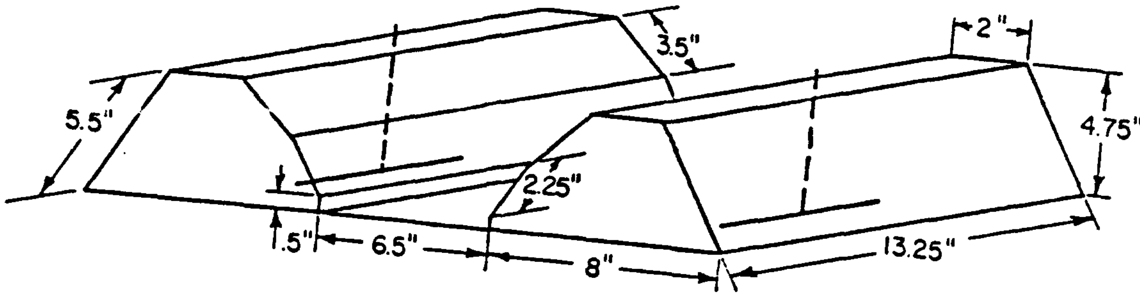
Sketch 3. 790 Symmetrical Head



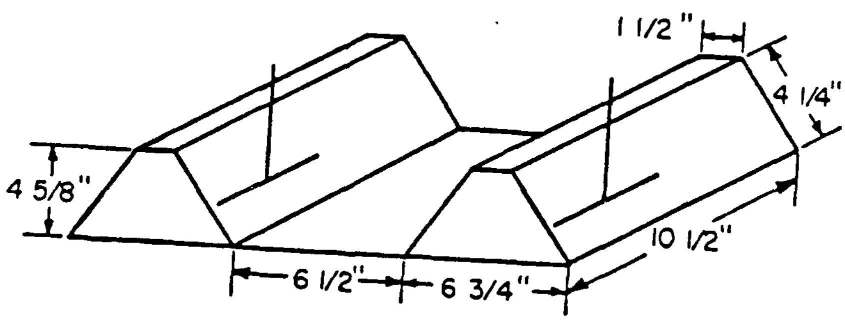
Sketch 4. Side-by-side Array Configuration



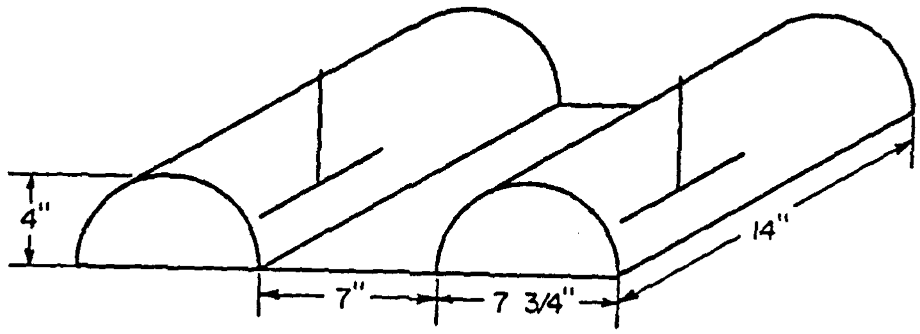
Sketch 5. Staggered Array Configuration



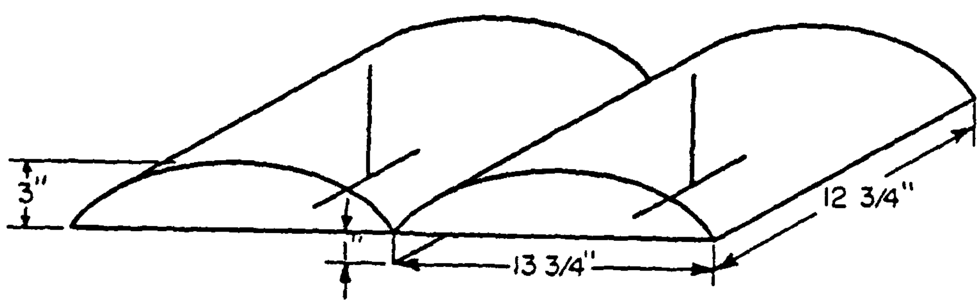
Sketch 6. 790 Nonsymmetrical Head



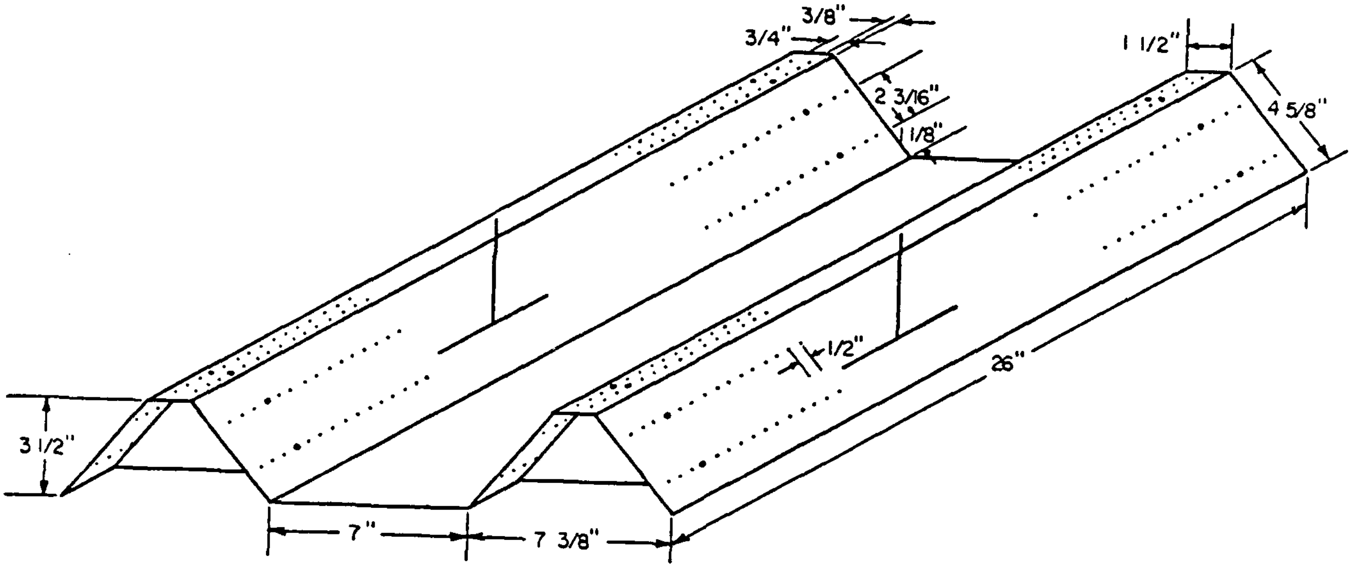
Sketch 7. 790 Symmetrical Head



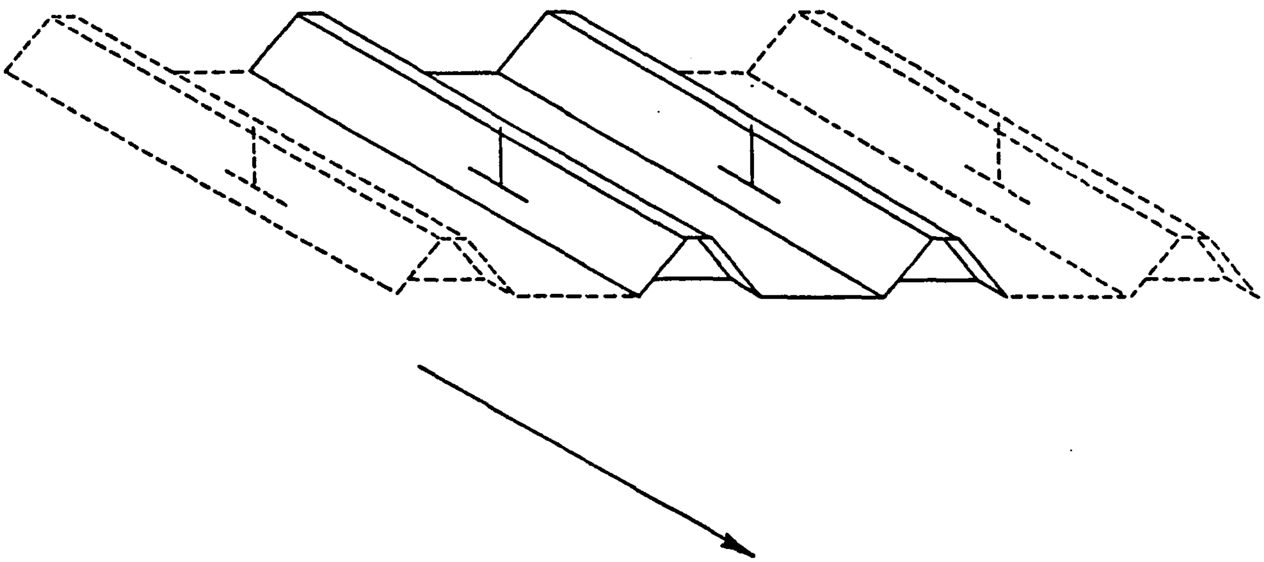
Sketch 8. 790 Cylinderical Head



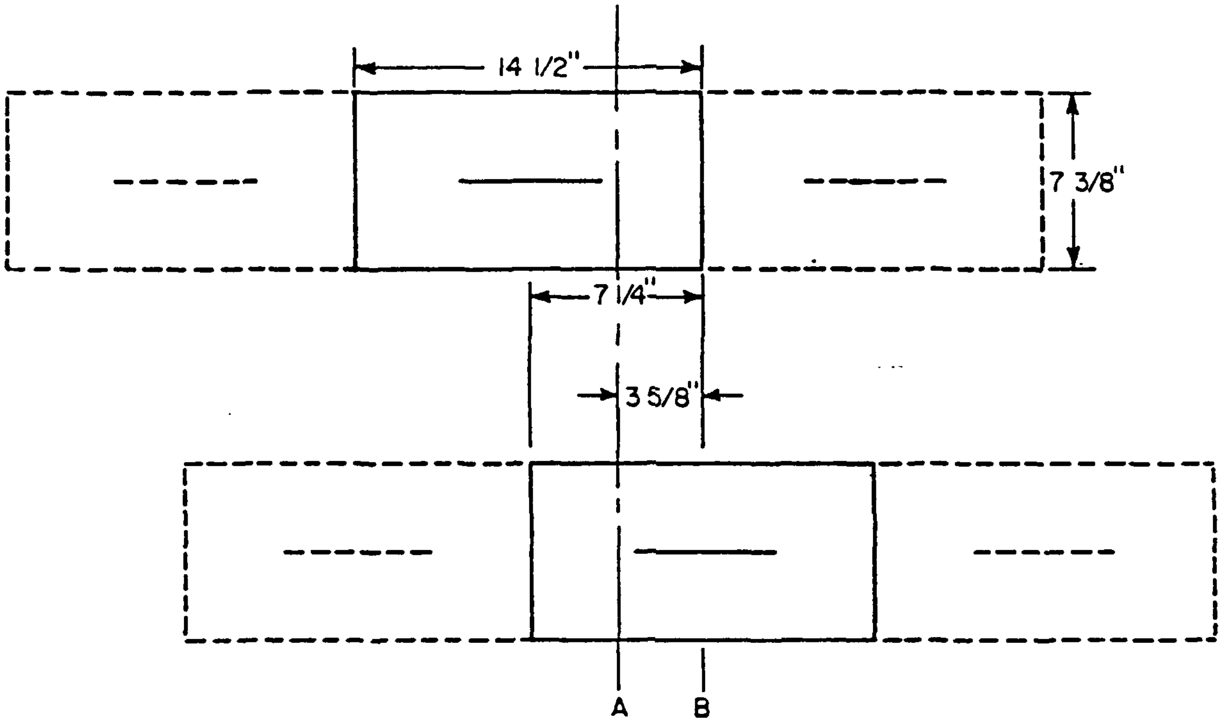
Sketch 9. Parabolic Head



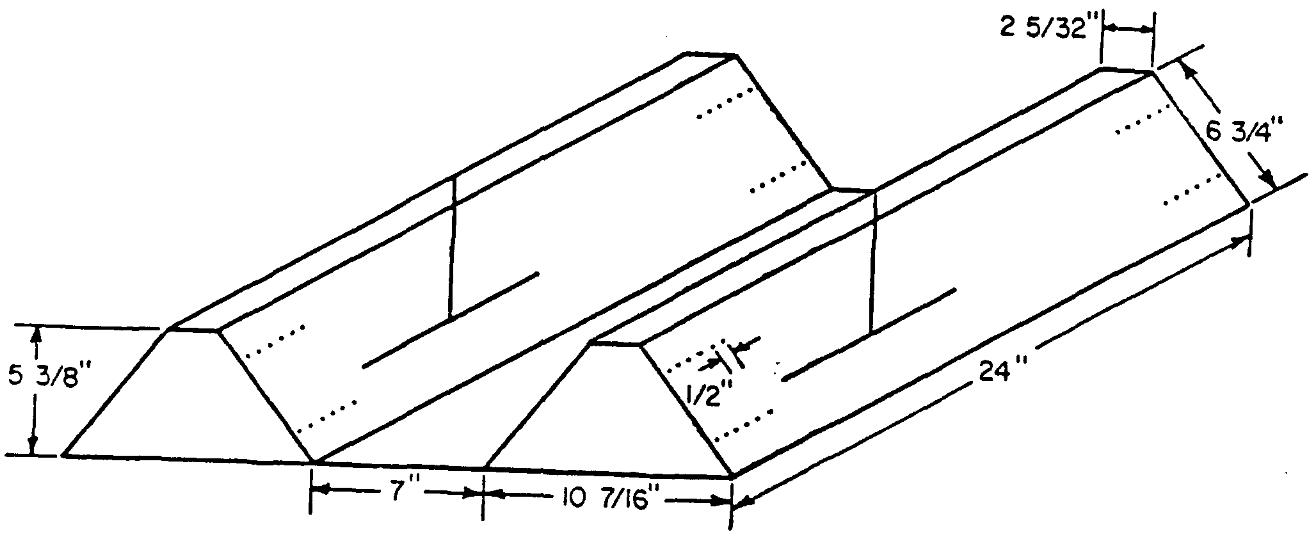
Sketch 10. Adjustable Width 790 Symmetrical Head



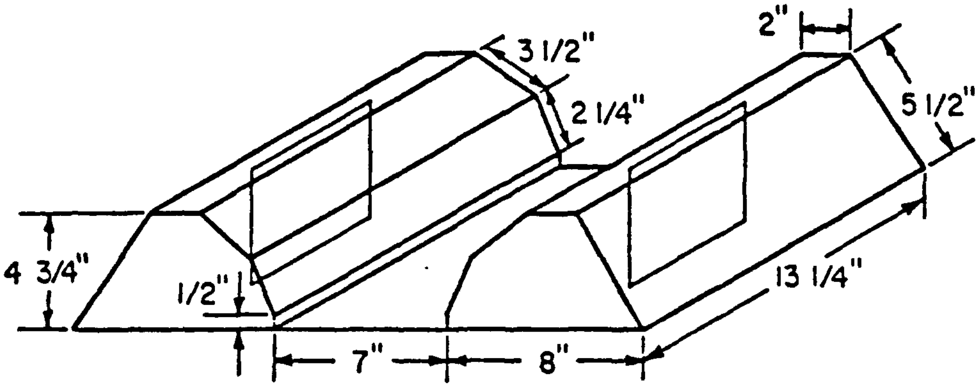
Sketch 11. 790 Symmetrical Head with
Dipoles parallel to direction of travel



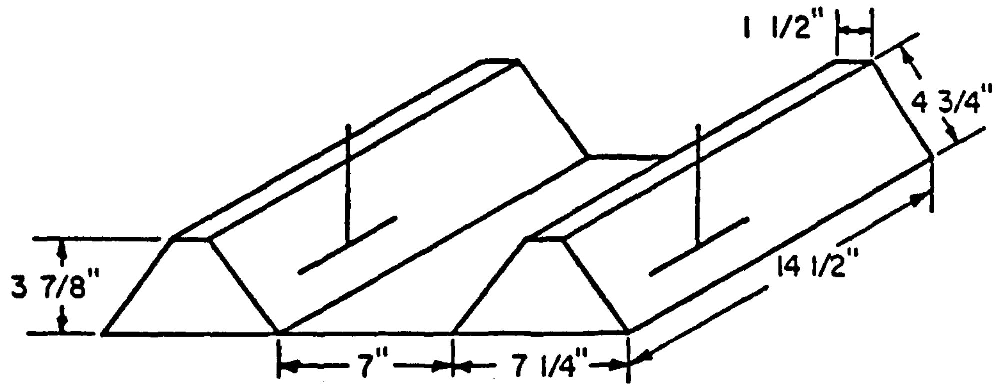
Sketch 12. Symmetrical Head Staggered 7.25 inches



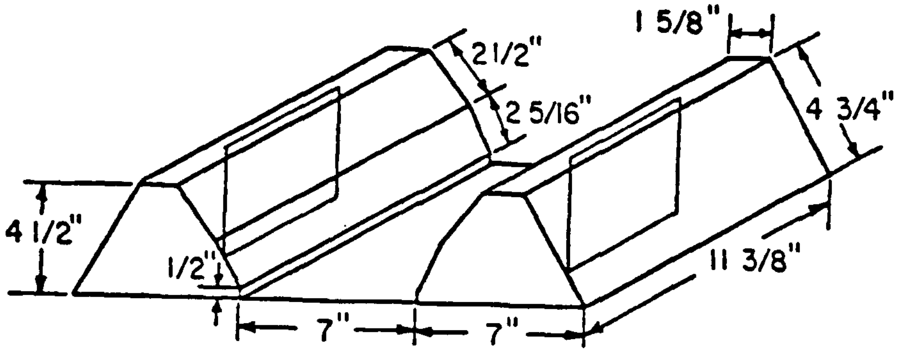
Sketch 13. Adjustable width 550 Symmetrical Head



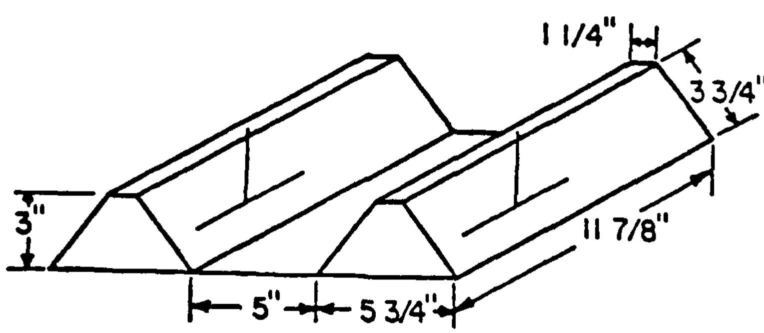
Sketch 14. 790 Nonsymmetrical Head



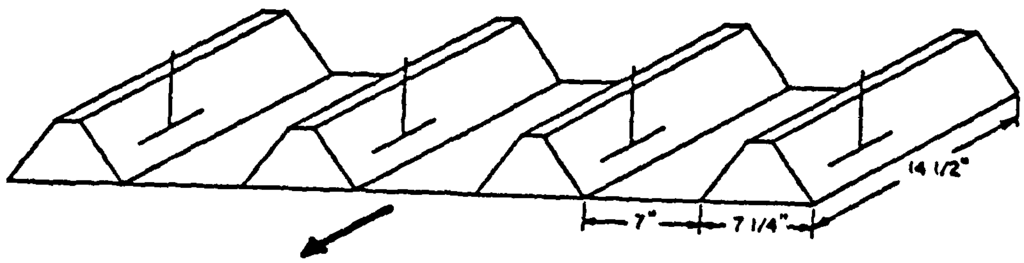
Sketch 15. 790 Symmetrical Head with adjustable Dipoles



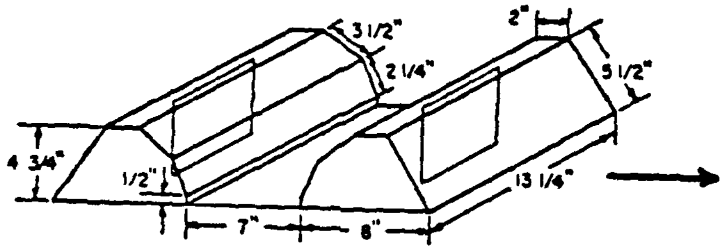
Sketch 16. 890 Nonsymmetrical Head



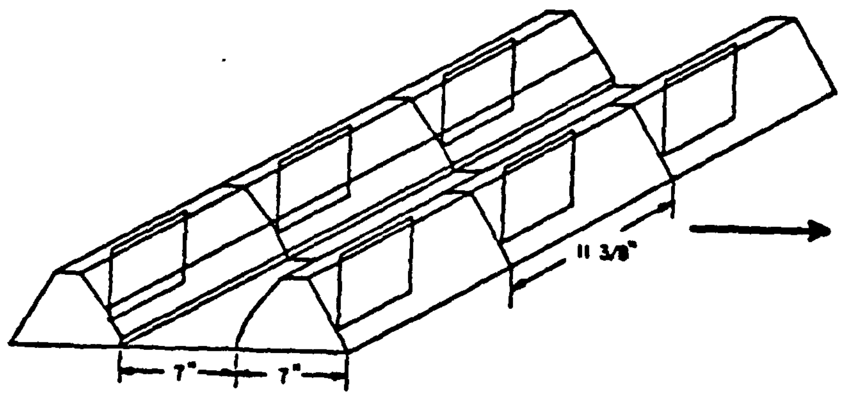
Sketch 17. 1 GHz Symmetrical Head with adjustable Dipoles



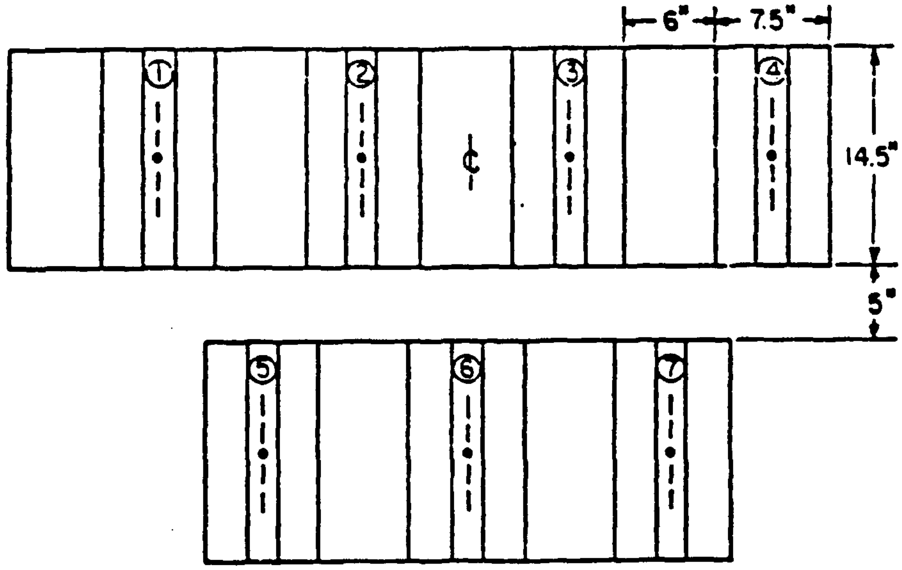
Sketch 18. 790 Symmetrical Head, wide (790 SYHW)



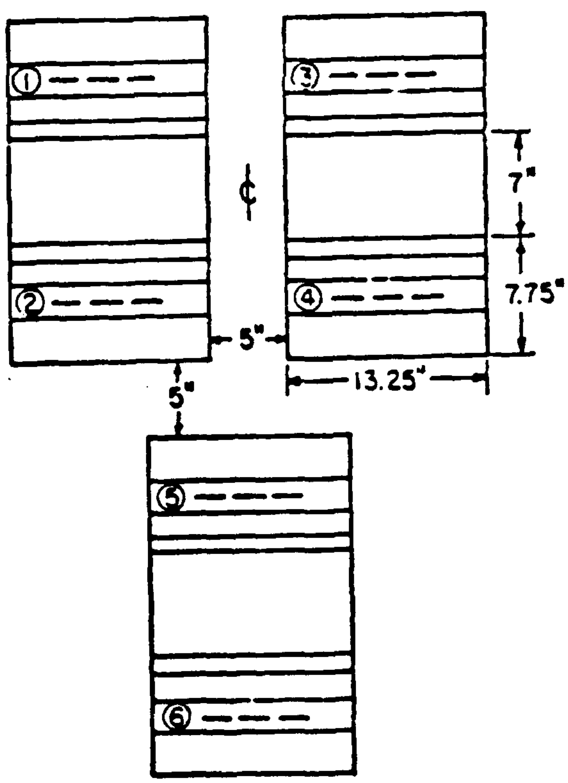
Sketch 19. 790 Nonsymmetrical Head



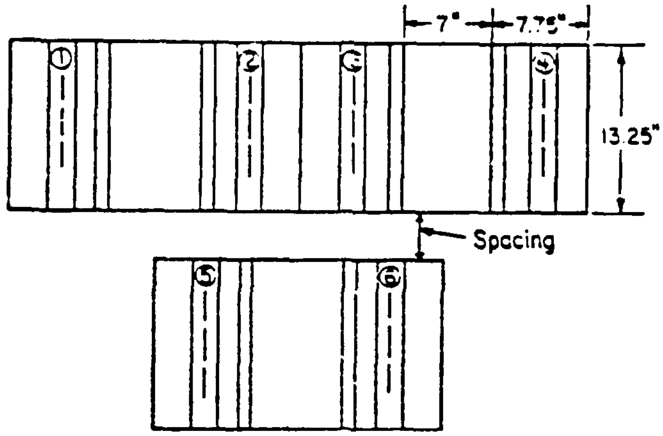
Sketch 20. 890 Nonsymmetrical Head



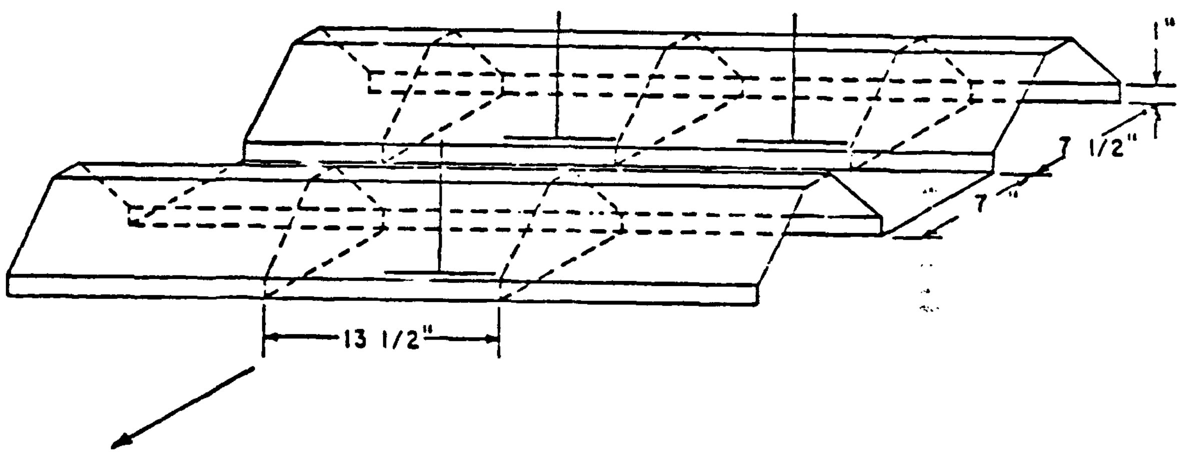
Sketch 21. Articulated double row array of
790 Nonsymmetrical Heads run at 0 degrees orientation



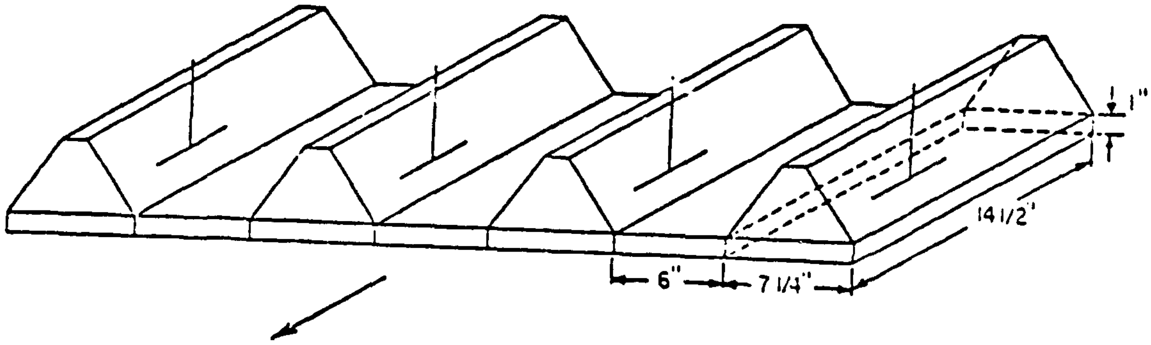
Sketch 22. Articulated double row array of
790 Symmetrical Heads run at 90 degrees orientation



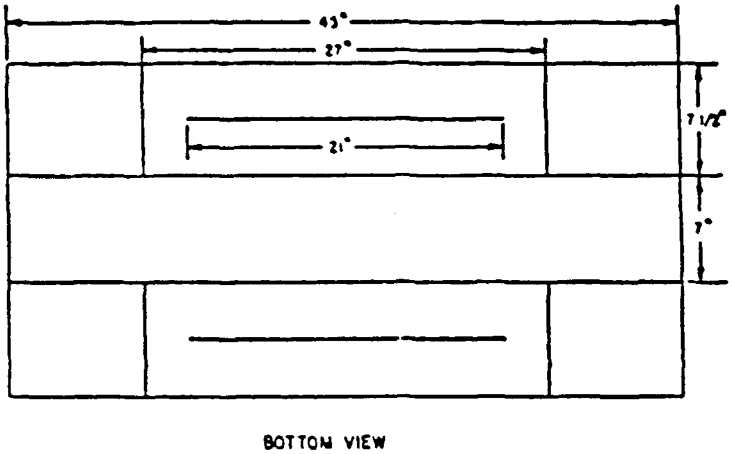
Sketch 23. Articulated double row array of 790 Nonsymmetrical Heads



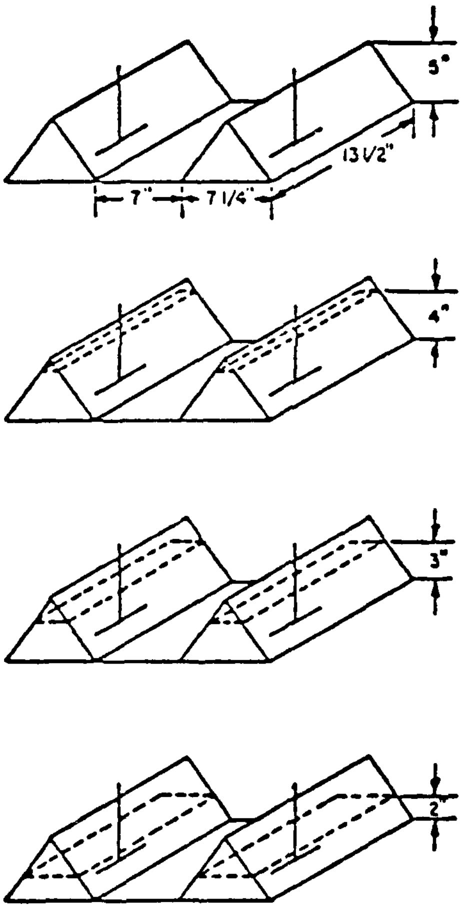
Sketch 24. 790 SYH staggered array run at 0 degrees



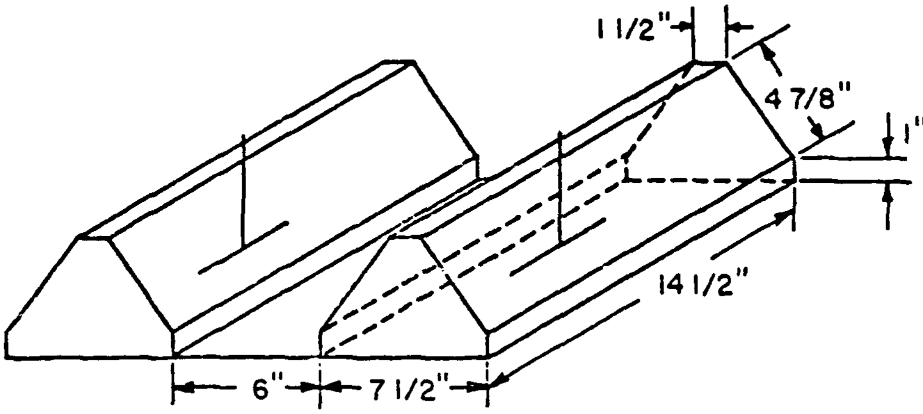
Sketch 25. 790 ar..y run at 90 degrees



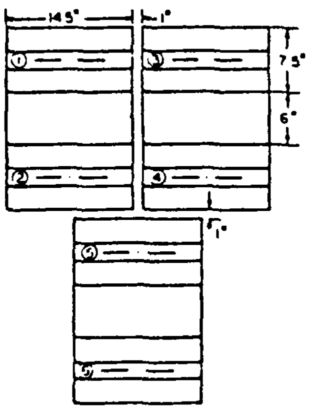
Sketch 26. 790 SYH with long Dipoles



Sketch 27. 790 SYH with Variable Depth Truncated Corner

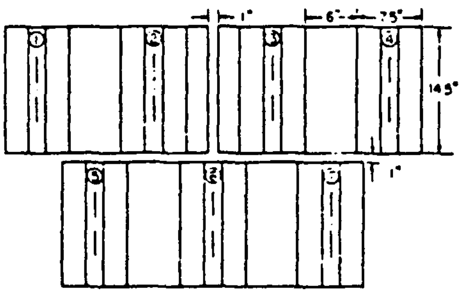


Sketch 28. 790 Symmetrical Head



790 Symmetrical Head Array

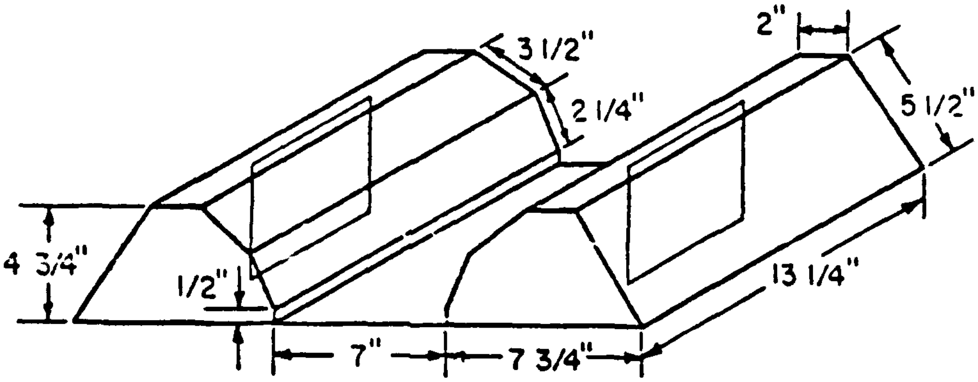
0° Orientation



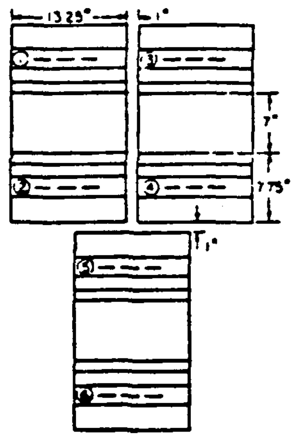
790 Symmetrical Head Array

90° Orientation

Sketch 29.

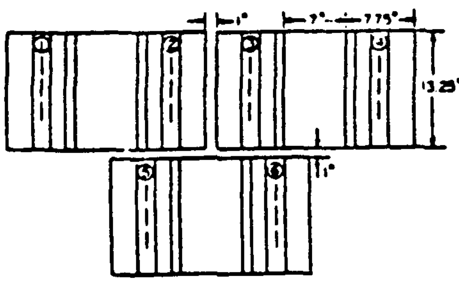


Sketch 30. 790 Nonsymmetrical Head



790 Nonsymmetrical Head Array

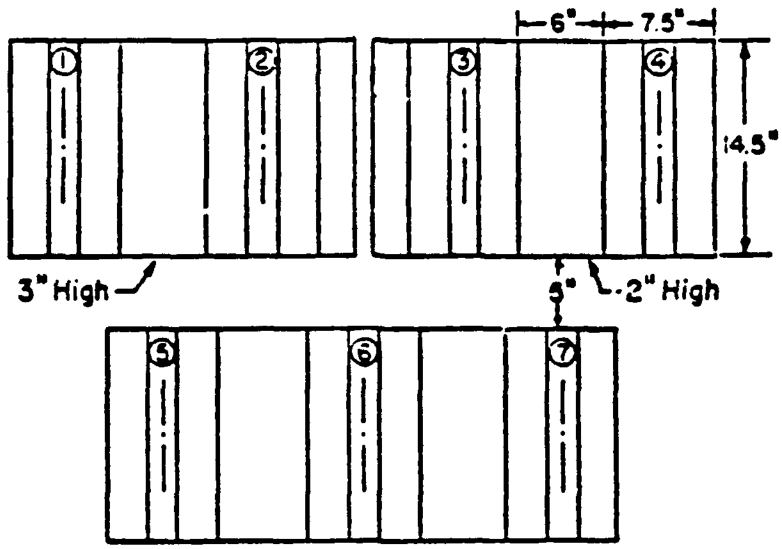
0° Orientation



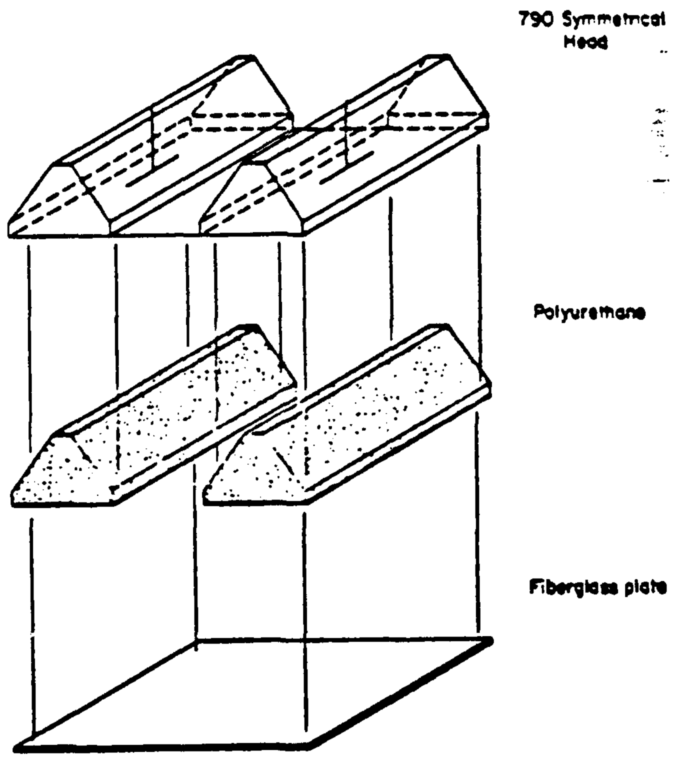
790 Nonsymmetrical Head Array

90° Orientation

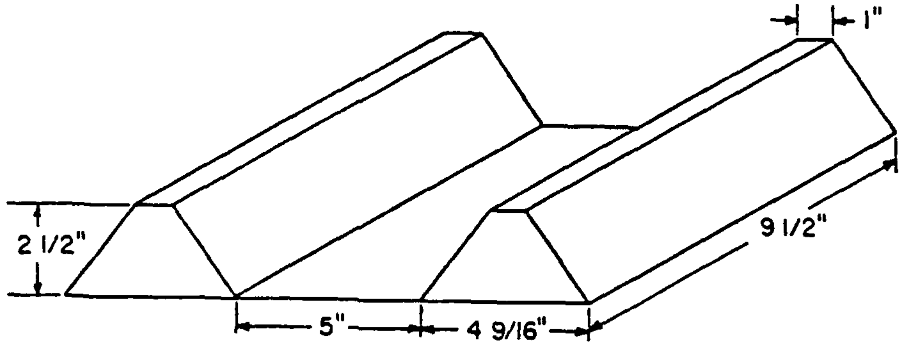
Sketch 31.



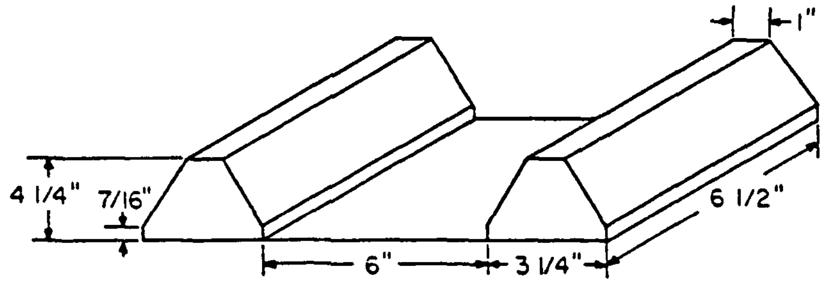
Sketch 32. Double row array of 790 Symmetrical Heads run at 90 degrees



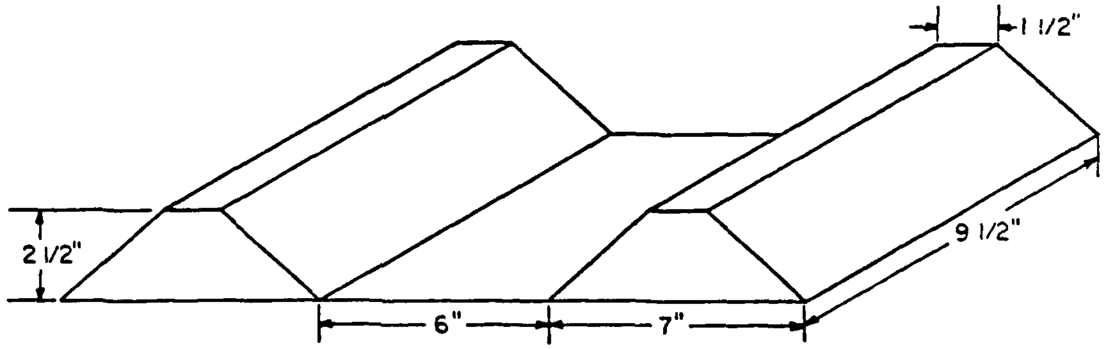
Sketch 33. Assembly of 790 Symmetrical Head
with polyurethane fill and fiberglass plate



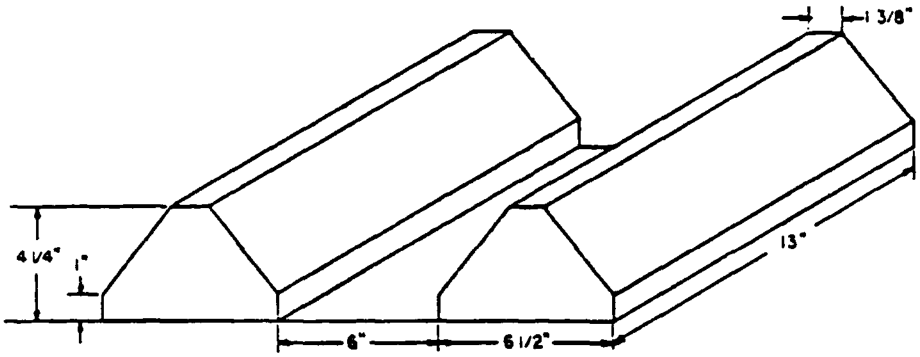
Sketch 34. Lucite-filled Symmetrical Head



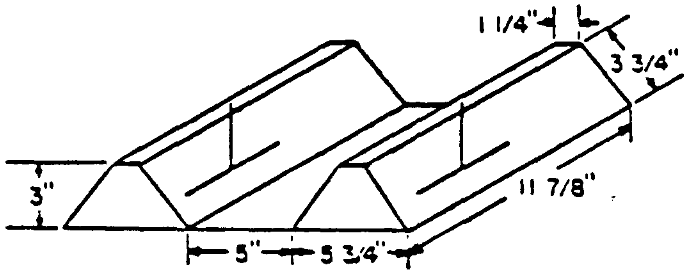
Sketch 35. Original Dielectric Foam-filled Head



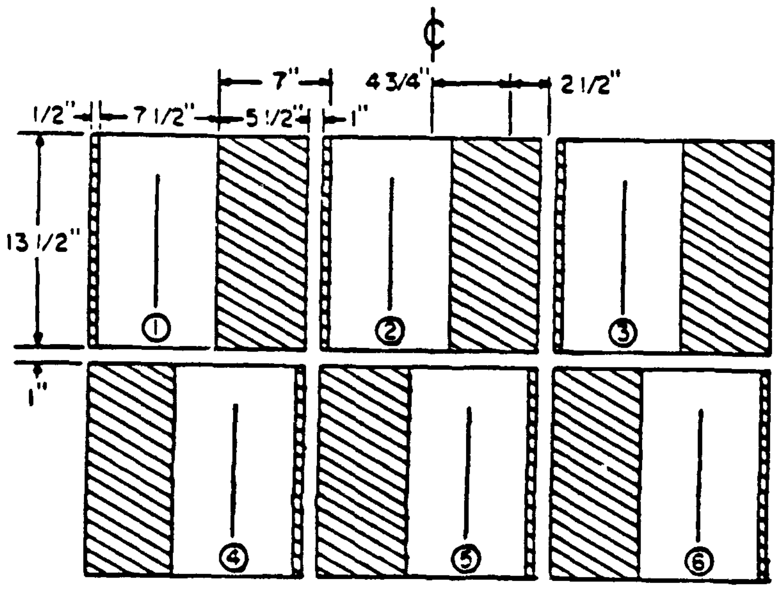
Sketch 36. Modified High Dielectric Foam-filled Head



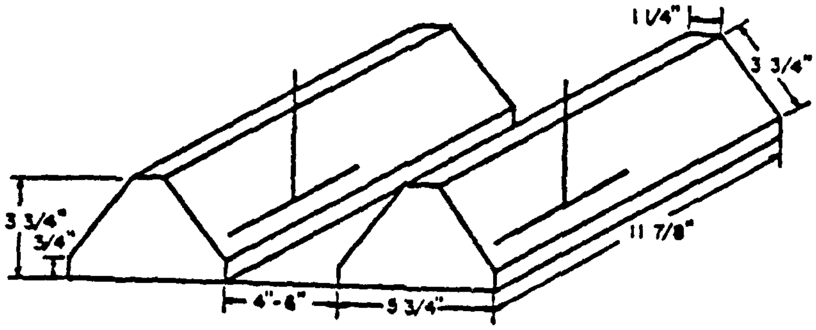
Sketch 37. 900 MHz Symmetrical Head with "Skirt"



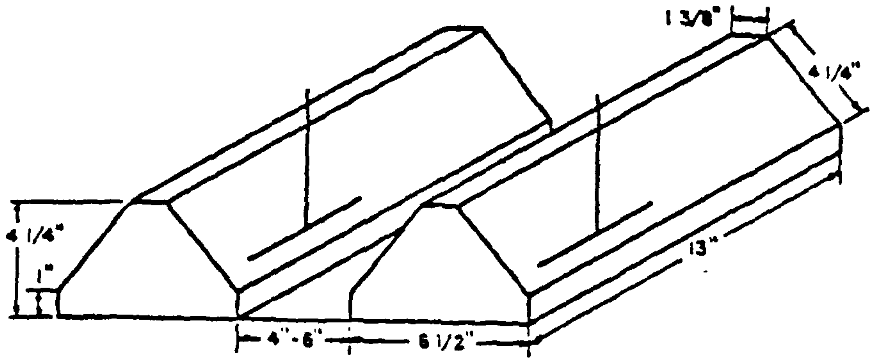
Sketch 38. 1 GHz Symmetrical Head



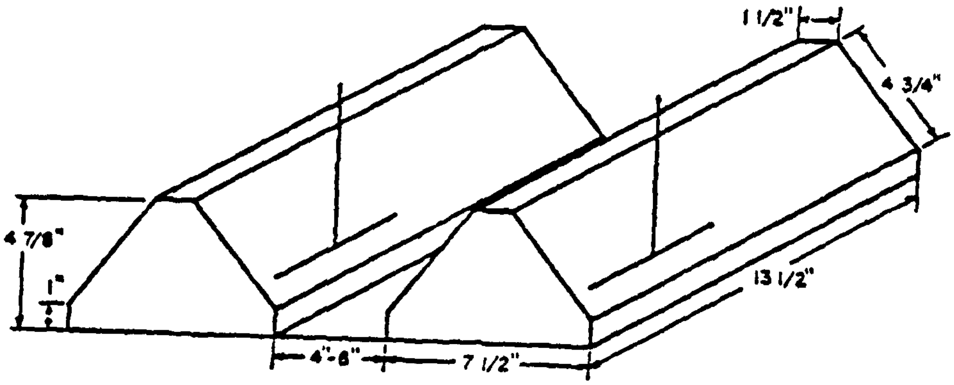
Sketch 39. Double row array of 790 Symmetrical Heads run at 90 degrees



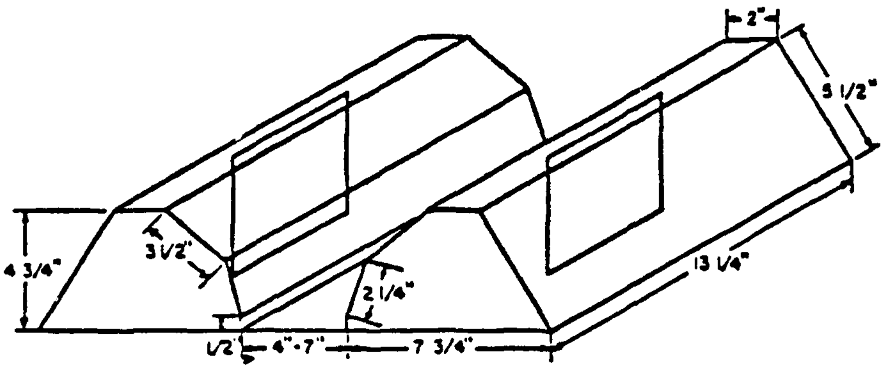
Sketch 40. 1 GHz Symmetrical Head with "Skirt"



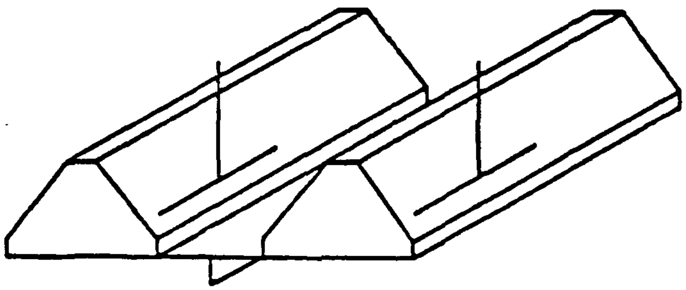
Sketch 41. 900 MHz Symmetrical Head



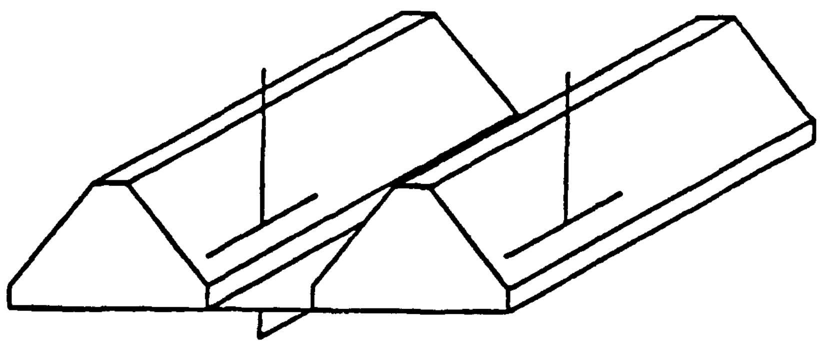
Sketch 42. 790 MHz Symmetrical Head



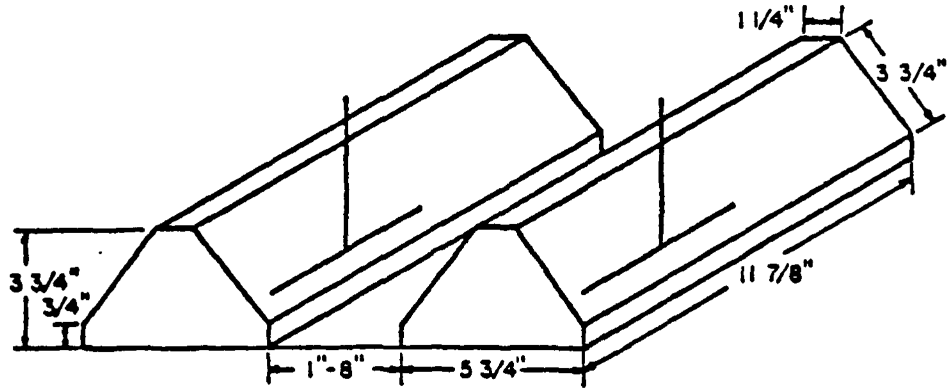
Sketch 43. 790 MHz Nonsymmetrical Head with printed circuit Dipoles



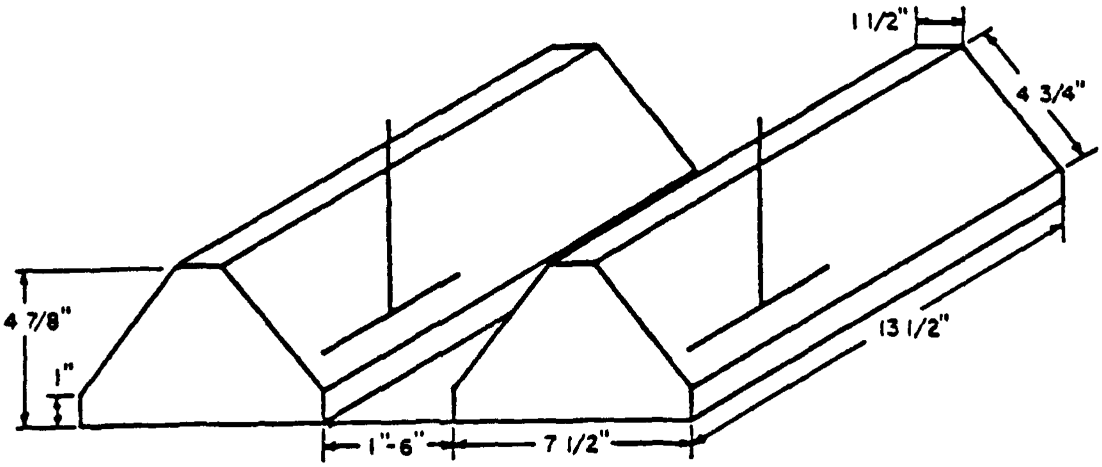
Sketch 44. 1 GHz Head with 1" Fin



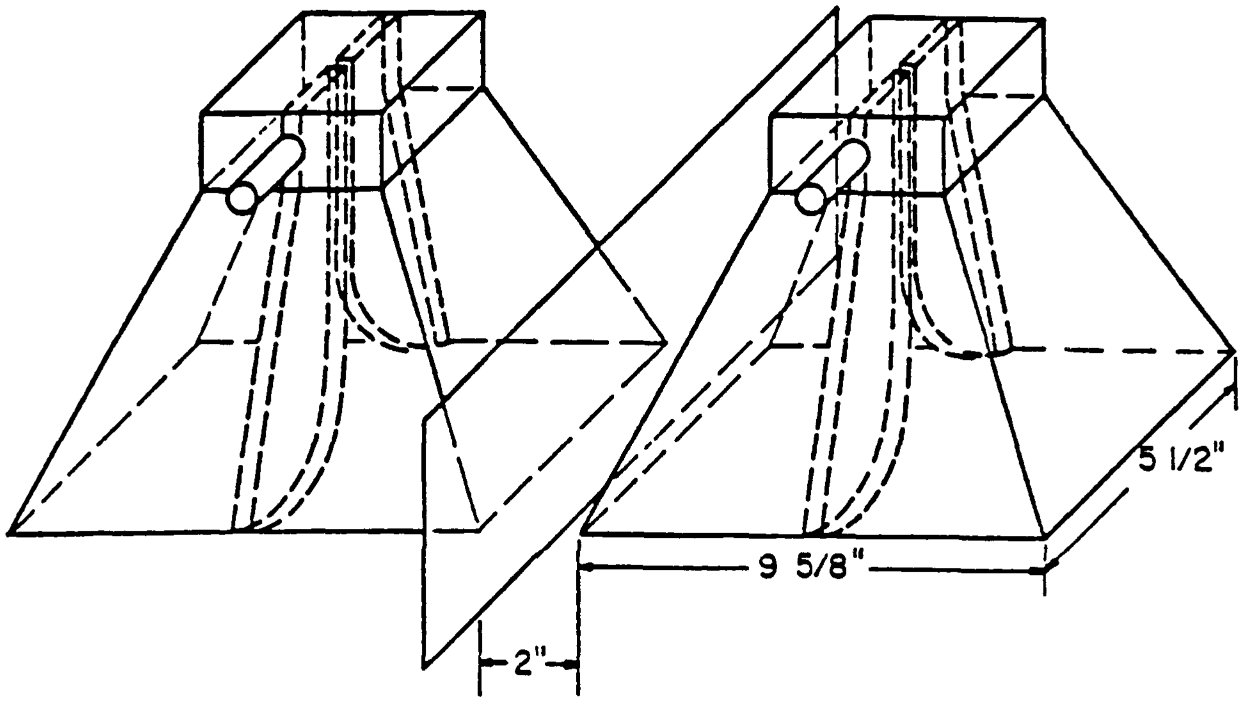
Sketch 45. 790 SYH Head with 1" Fin



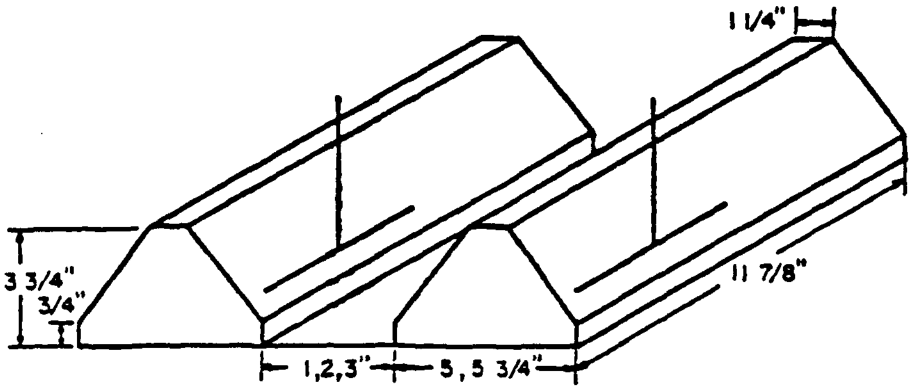
Sketch 46. 1 GHz Symmetrical Head



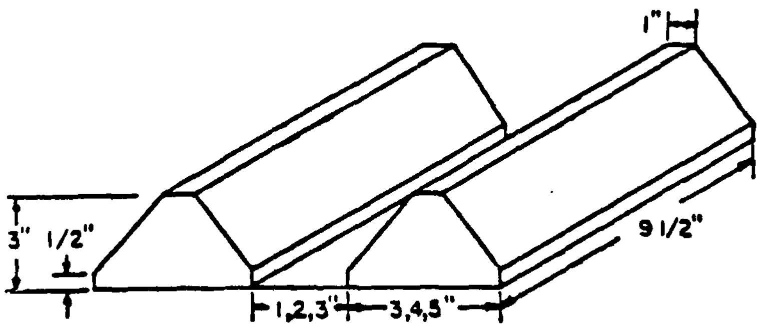
Sketch 47. 790 MHz Symmetrical Head



Sketch 48. Parallel Polarized Ridged Waveguide Horns



Sketch 49. 1 GHz Symmetrical Head



Sketch 50. 1.2 GHz Symmetrical Head

APPENDIX B. EXPERIMENT LISTING

This listing briefly describes the purpose, conditions, and results for most of the experiments included in the reports from which this summary was compiled. The original report describing the experiment is also indicated.

Most of the different items shown for each experiment are self explanatory; a few are not. The "Reference No." is a chronological number used to identify the entry. The number called "Comparison series" identifies the experiments that are part of a particular series of comparison measurements made during a calender year. Thus, 77-3 would indicate the third series in 1977. An entry left blank indicates the information was not included in the report nor is otherwise available. The frequency range is given in MHz, except for reference number 58 where it is in GHz.

Reference No: 1
Head: 670 NSYH (nonsymmetrical head) | Head sketch No:

Dipole type: Printed circuit | Frequency range: 550-750
Heights: 1, 3, 5"
Septum width: 6"

Location: Large wood "sandbox" outside lab. | Approximate date: 5/15/72
Targets & depths: ZP: 4 | Soil moisture:

Reference report: Untitled, informal report | Comparison series: 72-1

Experiment: Head had no end plates. Comparison with corner reflector.

Result: Baseline response for the original Cubic head.

Reference No: 2
Head: 3CRAHF - corner reflector with 3 pair of dipoles. | Head sketch No:

Dipole type: Not known | Frequency range: 550-730
Heights: 1, 3, 5"
Septum width:

Location: Large wood "sandbox" outside lab. | Approximate date: 5/16/72
Targets & depths: ZP: 4 | Soil moisture:

Reference report: Untitled, informal report | Comparison series: 72-1

Experiment: Comparison with 670 NSYH (nonsymmetrical head). Head run with and without endplates and variety of dipole configurations.

Result: Large amount of data with no conclusion drawn in the report. Subjective: generally not as good as the Cubic 670 NSYH run at the same time. Head not run again.

Reference No: 3
Head: 670 NSYH | Head sketch No:

Dipole type: Printed circuit | Frequency range: 590-790
Heights: 1, 3, 5"
Septum width:

Location: Large wood "sandbox" outside lab. | Approximate date: 7/1/72
Targets & depths: TMDB: 2,6,9 | Soil moisture: 10%

Reference report: 1972 report: "Intercomparison of a 670 Single Head,...") | Comparison series: 72-2

Experiment: A comparison with a 790 nonsymmetrical head and a 550 symmetrical head.

Result: Data presentation only good for subjective comparision. No conclusions in report.

Reference No: 4
Head: 790 NSYH

Head sketch No: 1

Dipole type: Printed circuit
Heights: 1, 3, 5"
Septum width: 6.5"

Frequency range: 690-890

Location: Large wood "sandbox" outside lab.
Targets & depths: TMDB: 2,6,9

Approximate date: 7/1/72
Soil moisture: 10%

Reference report: 1972 report: "Intercomparison of a 670 Single Head,...")

Comparison series: 72-2

Experiment: A comparison with a 670 nonsymmetrical head and a 550 symmetrical head.

Result: Subjective comparison indicates a better performance at 5" high than the other two heads.

Reference No: 5
Head: 550 SYH (symmetrical head)

Head sketch No: 2

Dipole type: Stoddard adjustable cylindrical
Heights: 1, 3, 5"
Septum width: 5.25"

Frequency range: 420-620

Location: Large wood "sandbox" outside lab.
Targets & depths: TMDB: 2,6,9

Approximate date: 7/1/72
Soil moisture: 10%

Reference report: 1972 report: "Intercomparison of a 670 Single Head,...")

Comparison series: 72-2

Experiment: A comparison with a 670 NSYH and a 790 NSYH.

Result: Best response at 520 MHz. Does better than other two at 3", but not as well at 5" high.

Reference No: 6
Head: 550 SYH

Head sketch No: 2

Dipole type: Stoddard adjustable cylindrical
Heights: 2, 3, 4, 5"
Septum width: 5.25"

Frequency range: 590-790

Location: Large wood "sandbox" outside lab.
Targets & depths: TMDB: 2,6,9

Approximate date: 8/1/72
Soil moisture: 8%

Reference report: 1972 report: "Intercomparison of a 670 Single Head,...")

Comparison series: 72-3

Experiment: Dipole set for 690 MHz (for more direct comparison with 670 NSYH). Repeat of series 72-2 with added heights.

Result: The 550 head at 690 MHz is definitely worse than the response at 520 MHz and worse than the other two heads.

Reference No: 7
Head: 670 NSYH

Head sketch No:

Dipole type: Printed circuit
Heights: 2, 3, 4, 5"
Septum width:

Frequency range: 590-790

Location: Large wood "sandbox" outside lab.
Targets & depths: TMDB: 2,6,9

Approximate date: 8/1/72
Soil moisture: 8%

Reference report: 1972 report: "Intercomparison of a 670 Single Head,...")

Comparison series: 72-3

Experiment: Repeat of series 72-2 with added heights.

Result: No conclusions in report. Generally better (based on single freq plot) than 790 NSYH.

Reference No: 8
Head: 790 NSYH

Head sketch No: 1

Dipole type: Printed circuit
Heights: 2, 3, 4, 5"
Septum width: 6.5"

Frequency range: 690-890

Location: Large wood "sandbox" outside lab.
Targets & depths: TMDB: 2,6,9

Approximate date: 8/1/72
Soil moisture: 8%

Reference report: 1972 report: "Intercomparison of a 670 Single Head,...")

Comparison series: 72-3

Experiment: Repeat of series 72-2 with added heights.

Result: No conclusions in report. Certainly better than 550 at 690 MHz.

Reference No: 9
Head: 670 NSYH

Head sketch No:

Dipole type: Printed circuit
Heights: 1, 2, 3, 4, 5"
Septum width:

Frequency range:

Location: Large wood "sandbox" outside lab.
Targets & depths: M19: 2,6,9; TMDB: 2,6,9

Approximate date: 8/29/72
Soil moisture: 7 - 11%

Reference report: Aug 15 - Oct 13, 1972, Progress Report

Comparison series: 72-4

Experiment: Reference head for this series. Comparisons with 790 NSYH and 450 NSYH with soil moisture increasing.

Result: Good response to 5" high with little degradation with increased moisture.

Reference No: 10
Head: 670 NSYH with bow-tie

Head sketch No:

Dipole type: Bow-tie (exact design not available)
Heights: 3, 4, 5"
Septum width:

Frequency range: 340-620

Location: Large wood "sandbox" outside lab.
Targets & depths: TMDB: 2,6,9

Approximate date: 9/7/72
Soil moisture: 9.6%

Reference report: Aug 15 - Oct 13, 1972, Progress Report

Comparison series: 72-4

Experiment: An effort to get a broadband head.

Result: Broadband dipole did not produce a broadband head.

Reference No: 11
Head: 790 NSYH

Head sketch No: 1

Dipole type: Printed circuit
Heights: 1, 2, 3, 4, 5"
Septum width: 5.5, 6.5, 7.5

Frequency range: 700-900

Location: Large wood "sandbox" outside lab.
Targets & depths: M19: 2,6,9; TMDB: 2,6,9

Approximate date: 8/31/72
Soil moisture: 8 - 14.6%

Reference report: Aug 15 - Oct 13, 1972, Progress Report

Comparison series: 72-4

Experiment: Comparisons with 670 NSYH and 450 NSYH with soil moisture increasing. Also tried 3 septum widths.

Result: Working height limited to 4". Wider septum did not allow greater working height. Standard 6.5" still best. Best performance in comparison when moisture < 8.5%.

Reference No: 12
Head: 450 NSYH

Head sketch No:

Dipole type: Printed circuit
Heights: 1, 2, 3, 4, 5"
Septum width:

Frequency range: 380-520

Location: Large wood "sandbox" outside lab.
Targets & depths: M19: 2,6,9; TMDB: 2,6,9

Approximate date: 8/29/72
Soil moisture: 8 - 14.6%

Reference report: Aug 15 - Oct 13, 1972, Progress Report

Comparison series: 72-4

Experiment: A lower frequency head to try for higher working height and wet soil performance. Also tried putting 450 dipoles in 670 NYSH.

Result: Does give improved response in wet soil (8.5%+) and greater range of working heights. Best performance in comparison when moisture > 8.5%, although does not see targets at 14.6% (saturated)

Reference No: 13
Head: 670 NSYH triple head

Head sketch No:

Dipole type: Printed circuit
Heights: 1, 2, 3, 4"
Septum width:

Frequency range: 600-800

Location: Large wood "sandbox" outside lab.
Targets & depths: M19: 2,6,9; TMDB: 2,6,9

Approximate date: 8/28/72
Soil moisture: 7%

Reference report: Aug 15 - Oct 13, 1972, Progress Report

Comparison series: 72-4

Experiment: Larger reflector with 3 sets of dipoles located at various positions. Also tried end plates covered with ferrite absorbing material.

Result: Did not work well. Ferrite did not help. Later went to side-by-side single heads.

Reference No: 14
Head: 790 NSYH triple head

Head sketch No: 1

Dipole type: Printed circuit
Heights: 1, 2, 3, 4"
Septum width: 6.5"

Frequency range: 700-900

Location: Large wood "sandbox" outside lab.
Targets & depths: M19: 2,6,9; TMDB: 2,6,9

Approximate date: 8/31/72
Soil moisture: 10%

Reference report: Aug 15 - Oct 13, 1972, Progress Report

Comparison series: 72-4

Experiment: Larger reflector with 3 sets of dipoles located at different positions during the measurements.

Result: Did not perform well.

Reference No: 15
Head: 670 NSYH (multiple single head, side-by-side)

Head sketch No: 4,5

Dipole type: Printed circuit
Heights: 3"
Septum width:

Frequency range: 600-800

Location: Large wood "sandbox" outside lab.
Targets & depths: M19: 2,6,9; TMDB: 2,6,9

Approximate date: 8/30/72
Soil moisture: 10%

Reference report: Aug 15 - Oct 13, 1972, Progress Report

Comparison series: 72-5

Experiment: 1st experiments using an array to obtain coverage. Staggered configuration also tried (receive dipole midway way between 2 transmit)

Result: Works, and not effected by the other adjacent heads. The offset arrangement works, but not well.

Reference No: 16
Head: 790 MSYH (multiple single head, side-by-side) Head sketch No: 1,4,5

Dipole type: Printed circuit Frequency range: 700-900
Heights: 3"
Septum width: 6.5"

Location: Large wood "sandbox" outside lab. Approximate date: 9/18/72
Targets & depths: M19: 2,6,9; TMDB: 2,6,9 Soil moisture: 8.5%

Reference report: Aug 15 - Oct 13, 1972, Progress Report Comparison series: 72-5

Experiment: 1st experiments using an array to obtain coverage. Staggered configuration also tried (receive dipole midway way between 2 transmit)

Result: Works, and not effected by the other adjacent heads. The offset arrangement works, but not well. Overall, performs better than 670, possibly because of smaller physical size.

Reference No: 17
Head: 790 MSYH Head sketch No: 1

Dipole type: Printed circuit Frequency range: 690 - 890
Heights: 3" only reported
Septum width: 6.5"

Location: NBS field site Approximate date: 10/16/72
Targets & depths: TMDB: 2,6,9 Soil moisture: 7 - 9.6%

Reference report: 4th Qtr., 1972 Progress Report Comparison series: 72-6

Experiment: Series of exp. at new NBS field site: indoor rock-free, outdoor rock-free, and outdoor with rocks.

Result: Problem with shallow targets under dry conditions.

Reference No: 18
Head: 670 MSYH Head sketch No:

Dipole type: Printed circuit Frequency range: 590 - 790
Heights: 3" only reported, other heights run
Septum width:

Location: NBS field site Approximate date: 10/18/72
Targets & depths: TMDB: 2,6,9 Soil moisture: 7 - 9.8%

Reference report: 4th Qtr., 1972 Progress Report Comparison series: 72-6

Experiment: Series of exp. at new NBS field site: indoor rock-free, outdoor rock-free, and outdoor with rocks.

Result: Response similar to 790, except in rocky soil, where it is worse.

Reference No: 19
Head: 450 NSYH

Head sketch No:

Dipole type: Printed circuit
Heights: 3" only reported, other heights run
Septum width:

Frequency range: 360 - 560

Location: NBS field site
Targets & depths: TMDB: 2,6,9

Approximate date: 10/20/72
Soil moisture: 7 - 9.6%

Reference report: 4th Qtr., 1972 Progress Report

Comparison series: 72-6

Experiment: Series of exp. at new NBS field site: indoor rock-free, outdoor rock-free, and outdoor with rocks.

Result: Works very well, but because of large physical size (may havecoverage problems in an array), additional experiments not run with the reflector.

Reference No: 20
Head: 670 NSYH with 450 dipole

Head sketch No:

Dipole type: Printed circuit
Heights: 3" only reported, other heights run
Septum width:

Frequency range: 360 -560

Location: NBS field site
Targets & depths: TMDB: 2,6,9

Approximate date: 10/22/72
Soil moisture: 7 - 9.6%

Reference report: 4th Qtr., 1972 Progress Report

Comparison series: 72-7

Experiment: Several design changes (lowering septum and end plates) tried to improve performance.

Result: Configuration promising for shallow targets. Some improvement noted with changes. Work dropped because other heads seem more promising.

Reference No: 21
Head: 790 NSYH with 450 dipole

Head sketch No: 1

Dipole type: Printed circuit
Heights: 3" only reported, other heights run
Septum width: 6.5"

Frequency range: 360 -560

Location: NBS field site
Targets & depths: TMDB: 2,6,9

Approximate date: 10/24/72
Soil moisture: 7%

Reference report: 4th Qtr., 1972 Progress Report

Comparison series: 72-7

Experiment: Just to try it.

Result: Very narrow band, performance deteriorates rapidly above 3" high. No further work planned.

Reference No: 22
Head: 670 NSYH with adjustable dipole
Head sketch No:

Dipole type: Adjustable, cylindrical
Heights: 3" only reported, other heights run
Septum width:
Frequency range:

Location: NBS field site, inside only
Targets & depths: TMDB: 2,6,9
Approximate date: 10/24/72
Soil moisture: 4.9 - 5.5%

Reference report: 4th Qtr., 1972 Progress Report
Comparison series: 72-8

Experiment: Comparisons with dipole tuned to 480, 550, & 800 MHz. and located in various positions in the head.

Result: Best response at 480 MHz and dipoles set 1" below septum.

Reference No: 23
Head: 550 SYH (symmetrical head)
Head sketch No: 2

Dipole type: Adjustable and fixed cylindrical
Heights: 3" only reported, other heights run
Septum width: 5.25"
Frequency range: 420 -620

Location: NBS field site, inside only
Targets & depths: TMDB: 2,6,9
Approximate date: 10/30/72
Soil moisture: 4.9 - 8.4%

Reference report: 4th Qtr., 1972 Progress Report
Comparison series: 72-9

Experiment: New symmetrical design. Experiments with septum and end and back plate configuration.

Result: Very good results at 520 MHz with 2" lowered septum.

Reference No: 24
Head: 550 SYH
Head sketch No: 2

Dipole type: 450 and 670 printed circuit
Heights: 3" only reported, other heights run
Septum width: 5.25"
Frequency range:

Location: NBS field site, inside only
Targets & depths: TMDB: 2,6,9
Approximate date: 11/2/72
Soil moisture: 6.1%

Reference report: 4th Qtr., 1972 Progress Report
Comparison series: 72-9

Experiment: Test of SYH head using the 450 and 670 printed circuit dipoles.

Result: The 670 printed circuit dipoles did not work at all in the reflector. The 450 dipoles worked, but the elements are 2" below septum. The p.c. dipole may need the nonsymmetrical design to work.

Reference No: 25
Head: 670 NSYH with bowtie antenna — Head sketch No:

Dipole type: Wideband bowtie — Frequency range: 380 - 580
Heights: 3"
Septum width:

Location: NBS field site, inside only — Approximate date: 11/10/72
Targets & depths: TMDB: 2,6,9 — Soil moisture: 4.9%

Reference report: 4th Qtr., 1972 Progress Report — Comparison series: 72-10

Experiment: Another attempt to obtain a wideband head. A 450 head was also run.

Result: Free space wide band antenna does not seem to maintain it's bandwidth when placed in the reflector. Negative result.

Reference No: 26
Head: 550 SYH with mode filters — Head sketch No: 2

Dipole type: Adjustable cylindrical — Frequency range: 420 - 620
Heights: 3"
Septum width: 5.25"

Location: NBS field site, inside only — Approximate date: 11/20/72
Targets & depths: TMDB: 2,6,9 — Soil moisture: 4.2 - 5.5%

Reference report: 4th Qtr., 1972 Progress Report — Comparison series: 72-11

Experiment: Experiments with filter structures along the edge of the septum (in air gap between head and earth) to determine leakage modes.

Result: Experiments showed that modes are TE in the horizontal plane.

Reference No: 27
Head: 550 SYH field pattern and location — Head sketch No: 2

Dipole type: Fixed cylindrical; probes: 1.5" ext. center cond. — Frequency range: 420 - 620
Heights: 3"
Septum width: 5.25"

Location: NBS field site, inside only — Approximate date: 12/20/72
Targets & depths: TMDB: 6 — Soil moisture: 4.2%

Reference report: 4th Qtr., 1972 Progress Report — Comparison series: 72-12

Experiment: Use of electric field probes inside target to determine field pattern and mode blocks above target to determine where energy propagates.

Result: The strongest field component within the target is horizontal, parallel with the dipole. The mode experiments show energy transmission occuring between ground & top of target.

Reference No: 28
Head: 790 NSYH | Head sketch No: 1

Dipole type: Printed circuit | Frequency range: 690-890
Heights: 2, 3, 4, 5"
Septum width: 6.5"

Location: NBS field site, inside and outside | Approximate date: 1/15/73
Targets & depths: TMDB: 2,6,9 | Soil moisture: 4.5 - 7.8%

Reference report: Special Feb. 1973 report | Comparison series: 73-1

Experiment: This is a series comparing the standard 790 NSYH with a new 790 symmetrical head, scaled from the previously designed & tested 550 SYH.

Result: First use of average amplitude plots (TAD). The head occasionally misses targets, and generally did not perform as well as 790 SYH, especially outside.

Reference No: 29
Head: 790 SYH (symmetrical head) | Head sketch No: 3

Dipole type: Adjustable cylindrical | Frequency range: 690-890
Heights: 2, 3, 4, 5"
Septum width: 6"

Location: NBS field site, inside and outside | Approximate date: 1/15/73
Targets & depths: TMDB: 2,6,9 | Soil moisture: 4.5 - 7.8%

Reference report: Special Feb. 1973 report | Comparison series: 73-1

Experiment: This is a series comparing the standard 790 NSYH with a new 790 symmetrical head, scaled from the previously designed & tested 550 SYH.

Result: First use of average amplitude plots (TAD). The head did better in this comparison than the 790 NSYH, especially outside where moisture content was the highest.

Reference No: 30
Head: 790 NSYH | Head sketch No: 6

Dipole type: Adjustable cylindrical | Frequency range: 550-870
Heights: 3, 5"
Septum width: 6.5"

Location: NBS field site, inside and outside | Approximate date: 2/5/73
Targets & depths: PM-60: 1,2,4 | Soil moisture: 7.8 - 10.6%

Reference report: Progress Report, Jan-Mar, 1973 | Comparison series: 73-2

Experiment: A second series comparing the 790 NSYH with the 790 SYH. The dropped septum configuration on 790 SYH was eliminated for this series.

Result: The two heads, both with adjustable cylindrical dipoles, were nearly identical in performance.

Reference No: 31
Head: 790 SYH
Head sketch No: 7

Dipole type: Adjustable cylindrical
Frequency range: 550-870
Heights: 3, 5"
Septum width: 6.5"

Location: NBS field site, inside and outside
Approximate date: 2/5/73
Targets & depths: PM-60: 1,2,4
Soil moisture: 7.8 - 10.6%

Reference report: Progress Report, Jan-Mar, 1973
Comparison series: 73-2

Experiment: A second series comparing the 790 NSYH with the 790 SYH. The dropped septum configuration on 790 SYH was eliminated for this series.

Result: The two heads, both with adjustable cylindrical dipoles, were nearly identical in performance.

Reference No: 32
Head: 790 CYH (cylindrical head)
Head sketch No: 8

Dipole type: Adjustable cylindrical
Frequency range: 550-870
Heights: 3, 4, 5"
Septum width: 7"

Location: NBS field site, inside and outside
Approximate date: 2/10/73
Targets & depths: PM-60: 1,2,4
Soil moisture: 6.7 - 8.6%

Reference report: Progress Report, Jan-Mar, 1973
Comparison series: 73-3

Experiment: One of several shapes tried in an effort to optimize a symmetrical head, especially in the areas of bandwidth and coverage.

Result: Head responds over a slightly broader bandwidth (80 MHz) and performance (TAD plot) is slightly better than the 790 NSYH.

Reference No: 33
Head: 790 PAH (parabolic head)
Head sketch No: 9

Dipole type: Adjustable cylindrical and adjustable open-sleeve
Frequency range: 690-890
Heights: 3, 4, 5"
Septum width: 0 (fin)

Location: NBS field site, inside and outside
Approximate date: 2/15/73
Targets & depths: PM-60: 1,2,4
Soil moisture: 9.9 - 10.4%

Reference report: Progress Report, Jan-Mar, 1973
Comparison series: 73-3

Experiment: One of several shapes tried in an effort to achieve a symmetrical head with increased bandwidth and coverage.

Result: Compared with the 790 NSYH with p.c. dipoles, the 790 PAH is slightly better. Major negative factor is it's large size.

Reference No: 34
Head: 790 NSYH

Head sketch No: 6

Dipole type: Printed circuit
Heights: 3, 5"
Septum width: 6, 7, 8, 9"

Frequency range: 610-910

Location: NBS field site, inside and outside
Targets & depths: PM-60: 1,2,4

Approximate date: 3/20/73
Soil moisture: 5.4 - 7.0%

Reference report: Progress Report, Jan-Mar, 1973

Comparison series: 73-4

Experiment: A series of tests to determine the optimum septum width for this head.

Result: 7" is best septum width.

Reference No: 35
Head: 790 SYH

Head sketch No: 10,11,12

Dipole type: Adjustable cylindrical
Heights: 3"
Septum width: 7"

Frequency range: 610-910

Location: NBS field site, inside only
Targets & depths: PM-60: 1,2,4

Approximate date: 3/25/73
Soil moisture: 5.5%

Reference report: Progress Report, Jan-Mar, 1973

Comparison series: 73-5

Experiment: Initial series to determine the best head width and best configuration and way of combining heads to cover a road bed.

Result: Best head width: 13.5". Best coverage was obtained with a staggered head (dipole orientation perpendicular to travel) arrangement with transmit and receive heads offset 1/2 width.

Reference No: 36
Head: 550 SYH

Head sketch No: 13

Dipole type: Adjustable cylindrical
Heights: 3"
Septum width: 7"

Frequency range: 340-640

Location: NBS field site, inside only
Targets & depths: PM-60: 1,2,4

Approximate date: 3/30/73
Soil moisture: 5.2%

Reference report: Progress Report, Jan-Mar, 1973

Comparison series: 73-5

Experiment: To determine optimum head width and see to if the lower frequency head might offer better coverage than the 790 SYH.

Result: Best head width: 21.5" Does not offer any advantages in coverage over the 790 SYH.

Reference No: 37
Head: 790 NSYH

Head sketch No: 14

Dipole type: Printed circuit
Heights: 2, 3, 4, 5"
Septum width: 7"

Frequency range: 610-910

Location: 4 sites near Mineral Research Center
Targets & depths: PM-60:2,4,6,12; TMDB:2,4,12; M-15:4; M-19:2

Approximate date: 7/15/73
Soil moisture: 2 - 15%

Reference report: "Butte Montana Field Trip", July,1973

Comparison series: 73-6

Experiment: 4 heads: 790 NSYH, 890 NSYH, 790 SYH, & 1 GHz SYH. on unimproved trail, graveled road, & under asphalt in parking lot. Included coverage tests.

Result: Response at 4.5" is good, very poor wet performance, 0 degree coverage (head orientation parallel with travel) poor, relatively narrow bandwidth. Could not detect target beneath asphalt.

Reference No: 38
Head: 790 SYH

Head sketch No: 15

Dipole type: Adjustable cylindrical
Heights: 2, 3, 4, 4.5"
Septum width: 7"

Frequency range: 610-910

Location: 4 sites near Mineral Research Center
Targets & depths: PM-60:2,4,6,12; TMDB:2,4,12; M-15:4; M-19:2

Approximate date: 7/15/73
Soil moisture: 2 - 15%

Reference report: "Butte Montana Field Trip", July,1973

Comparison series: 73-6

Experiment: 4 heads: 790 NSYH, 890 NSYH, 790 SYH, & 1 GHz SYH. on unimproved trail, graveled road, & under asphalt in parking lot. Included coverage tests.

Result: Response at 4.5" is good, poor wet performance, 0 degree coverage poor, relatively wide bandwidth. Could not detect target beneath asphalt.

Reference No: 39
Head: 890 NSYH

Head sketch No: 16

Dipole type: Printed circuit
Heights: 2, 3, 4, 4.5"
Septum width: 7"

Frequency range: 710-1010

Location: 4 sites near Mineral Research Center
Targets & depths: PM-60:2,4,6,12; TMDB:2,4,12; M-15:4; M-19:2

Approximate date: 7/15/73
Soil moisture: 2 - 15%

Reference report: "Butte Montana Field Trip", July,1973

Comparison series: 73-6

Experiment: 4 heads: 790 NSYH, 890 NSYH, 790 SYH, & 1 GHz SYH. on unimproved trail, graveled road, & under asphalt in parking lot. Included coverage tests.

Result: Response with height is good, poor wet performance, 0 degree coverage very good, relatively narrow bandwidth. Could not detect target beneath asphalt.

Reference No: 40
Head: 1 GHz SYH

Head sketch No: 17

Dipole type: Adjustable cylindrical
Heights: 2, 3, 4, 4.5"
Septum width: 5"

Frequency range: 810-1110

Location: 4 sites near Mineral Research Center
Targets & depths: PM-60:2,4,6,12; TMDB:2,4,12; M-15:4; M-19:2

Approximate date: 7/15/73
Soil moisture: 2 - 15%

Reference report: "Butte Montana Field Trip", July,1973

Comparison series: 73-6

Experiment: 4 heads: 790 NSYH, 890 NSYH, 790 SYH, & 1 GHz SYH. on unimproved trail, graveled road, & under asphalt in parking lot. Included coverage tests.

Result: Response poor above 3", very good wet performance, very good 0 degree coverage.

Reference No: 41
Head: 790 SYHW ("wide" triple symmetrical head)

Head sketch No: 18

Dipole type: Adjustable cylindrical
Heights: 2, 3, 4"
Septum width: 7"

Frequency range: 610-910

Location: 3 field sites, Ft. Belvoir
Targets & depths: PM-60:1,2,3,4,6,9,12"; M-19:2,4,6; M-15:0,2

Approximate date: 10/15/73
Soil moisture: 3.7 - 10.5%

Reference report: "Ft Belvoir, Va, Field Trip" 10/73

Comparison series: 73-7

Experiment: 3 heads: 790 SYHW, 790 NSYH, & 890 NSYHW on three outdoor mine lanes with various metallic and non-metallic mines. Included coverage tests.

Result: Run 90 degrees (head orientation perpendicular to travel), does not give full coverage with single row of heads. Good height performance. Filled holes produce false alarms.

Reference No: 42
Head: 790 NSYH

Head sketch No: 19

Dipole type: Printed circuit
Heights: 2, 3, 4"
Septum width: 7"

Frequency range: 700-910

Location: 3 field sites, Ft. Belvoir
Targets & depths: PM-60:1,2,3,4,6,9,12"; M-19:2,4,6; M-15:0,2; M-14

Approximate date: 10/15/73
Soil moisture: 3.7 - 10.5%

Reference report: "Ft Belvoir, Va, Field Trip" 10/73

Comparison series: 73-7

Experiment: 3 heads: 790 SYHW, 790 NSYH, & 890 NSYHW on three outdoor mine lanes with various metallic and non-metallic mines. Included coverage tests.

Result: Was not run much because of problem with the pc dipoles (possible crack in pc board, although never definitely determined the cause).

Reference No: 43
Head: 890 NSYHW ("wide" - three single heads) — Head sketch No: 20

Dipole type: Printed circuit — Frequency range: 710-1010
Heights: 2, 3, 4"
Septum width: 7"

Location: 3 field sites, Ft. Belvoir — Approximate date: 10/15/73
Targets & depths: PM-60:1,2,3,4,6,9,12"; M-19:2,4,6; M-15:0,2; M-14 — Soil moisture: 3.7 - 10.5%

Reference report: "Ft Belvoir, Va, Field Trip" 10/73 — Comparison series: 73-7

Experiment: 3 heads: 790 SYHW, 790 NSYH, & 890 NSYHW on three outdoor mine lanes with various metallic and non-metallic mines. Included coverage tests.

Result: Run 0 degrees, does not give full coverage with side-by-side single heads. Poor height performance. Filled holes produce false alarms.

Reference No: 44
Head: 790 SYH array — Head sketch No: 21

Dipole type: Fixed cylindrical — Frequency range: 610-910
Heights: 4"
Septum width: 6"

Location: NBS field site, inside — Approximate date: 1/20/74
Targets & depths: PM-60:1,2,4 — Soil moisture: 3 - 4%

Reference report: Progress report Jan thru Mar, 1974 — Comparison series: 74-1

Experiment: Primarily, coverage comparison of 2 arrays made up of 1) 790 SYH & 2) 790 NSYH. Each array has two offset rows of heads with varying gaps.

Result: Modified head design gives significant improvement. Far superior in coverage when run with 2 rows. Head orientation (0 or 90 degrees) has minor influence on coverage.

Reference No: 45
Head: 790 NSYH array — Head sketch No: 22,23

Dipole type: Printed circuit — Frequency range: 610-910
Heights: 4"
Septum width: 7"

Location: NBS field site, inside — Approximate date: 2/10/74
Targets & depths: PM-60:1,2,4 — Soil moisture: 3 - 4%

Reference report: Progress report Jan thru Mar, 1974 — Comparison series: 74-1

Experiment: Primarily, coverage comparison of 2 arrays made up of 1) 790 SYH & 2) 790 NSYH. Each array has two offset rows of heads with varying gaps.

Result: Not as good in terms of coverage. Some advantage for articulated case (two rows that change height independently) in 0 degree orientation.

Reference No: 46
Head: 790 SYH, staggered
Head sketch No: 24

Dipole type: Adjustable cylindrical
Heights: 4"
Septum width: 7"
Frequency range: 610-910

Location: NBS field site, inside
Targets & depths: PM-60:1,2,6
Approximate date: 1/10/74
Soil moisture: 3 - 4%

Reference report: NBS Coverage Experiments, Jan 18, 1974
Comparison series: 74-2

Experiment: Testing configurations that might improve coverage. This arrangement has staggered transmit and recieve dipoles.

Result: 0 degrees orientation. Best results with dipoles 3/4" below 1" dropped septum (a vulnerable spot), 13.5" wide reflector, 6" wide septum. Inside, gave best results.

Reference No: 47
Head: 790 SYH, triple head array
Head sketch No: 25

Dipole type: Adjustable cylindrical
Heights: 3, 4"
Septum width: 6-7.5"
Frequency range: 610-910

Location: NBS field site, inside & outside
Targets & depths: PM-60:1,2,6
Approximate date: 1/10/74
Soil moisture: 3 - 4%

Reference report: NBS Coverage Experiments, Jan 18, 1974
Comparison series: 74-2

Experiment: Testing configurations that might improve coverage. These tests varied the height of the dipole within the reflector, the reflector width, & septum width.

Result: 90 degree orientation. Best with: 1" dropped septum, dipole recessed 3/8" or 3/4" up within head, 7.5" wide reflector, and a 6" septum width. Very good performance, inside and out.

Reference No: 48
Head: 790 SYH, single head
Head sketch No:

Dipole type: Adjustable cylindrical
Heights: 4"
Septum width: 6"
Frequency range: 610-910

Location: NBS field site, inside
Targets & depths: PM-60:1,2,6
Approximate date: 1/10/74
Soil moisture: 3 - 4%

Reference report: NBS Coverage Experiments, Jan 18, 1974
Comparison series: 74-2

Experiment: Testing configurations that might improve coverage. This experiment varies the height of the dipole and the reflector shape.

Result: For this single head, best results were obtained with the dipoles 3/4" below a 1" dropped septum - the opposite of the previous triple head case.

Reference No: 49
Head: 790 SYH, single head

Head sketch No:

Dipole type: Adjustable cylindrical
Heights: 4"
Septum width: 6"

Frequency range: 610-910

Location: NBS field site, inside
Targets & depths: PM-60:1,2,6

Approximate date: 1/10/74
Soil moisture: 3 - 4%

Reference report: NBS Coverage Experiments, Jan 18, 1974

Comparison series: 74-2

Experiment: Testing configurations that might improve coverage. This experiment moves the dipole to one side of the head.

Result: This approach did move the response maximum toward the side of the head, but also brought the background level up reducing real signal (signal-to background ratio). Approach not pursued.

Reference No: 50
Head: 790 SYH, long single head

Head sketch No: 26

Dipole type: Adjustable cylindrical
Heights: 2"
Septum width: 7"

Frequency range: 610-910

Location: NBS field site, inside
Targets & depths: PM-60:1,2,6

Approximate date: 1/12/74
Soil moisture: 3 - 4%

Reference report: NBS Coverage Experiments, Jan 18, 1974

Comparison series: 74-2

Experiment: Testing configurations that might improve coverage. This experiment tries a wide reflector (2 lambda) with a 3/2 lambda dipole.

Result: Works, but not well. Signal-to-background ratio is poor because of high background. Not pursued further.

Reference No: 51
Head: 790 SYH, truncated corner

Head sketch No: 27

Dipole type: Adjustable cylindrical
Heights: 3"
Septum width: 7"

Frequency range: 610-910

Location: NBS field site, inside
Targets & depths: PM-60:1,2,6

Approximate date: 1/12/74
Soil moisture: 3 - 4%

Reference report: NBS Coverage Experiments, Jan 18, 1974

Comparison series: 74-2

Experiment: Testing configurations that might improve coverage. This experiment tries reducing the depth of the corner reflector from 5" to 2".

Result: Little effect on performance. Possible way to design a head that is not so deep.

Reference No: 52
Head: 790 SYH, reflector width

Head sketch No:

Dipole type: Adjustable cylindrical
Heights: 3"
Septum width: 7"

Frequency range: 610-910

Location: NBS field site, inside
Targets & depths: PM-60:1,2,6

Approximate date: 1/12/74
Soil moisture: 3 - 4%

Reference report: NBS Coverage Experiments, Jan 18, 1974

Comparison series: 74-2

Experiment: Testing configurations that might improve coverage. This experiment tries reducing the width of the corner reflector from 14.5" to 7".

Result: Reduces signal-to-background ratio without improving coverage. Not pursued further.

Reference No: 53
Head: 790 SYH array

Head sketch No: 28,29

Dipole type: Adjustable cylindrical
Heights: 3"
Septum width: 6"

Frequency range: 610-910

Location: NBS field site, outside
Targets & depths: PM-60:1,2,6

Approximate date: 5/15/74
Soil moisture: 3%

Reference report: "Articulated Arrays", June 15, 1974

Comparison series: 74-3

Experiment: Coverage of 2 articulated (allows relative vertical movement of heads) arrays using 2 head designs: 790 SYH at 0 & 90 degrees, and 790 NSYH at 0 and 90.

Result: This head run at 90 degrees, generally gave the best response. With 1" head spacing, the articulated condition slightly reduces response; at 5", not so much.

Reference No: 54
Head: 790 NSYH array

Head sketch No: 30,31

Dipole type: Printed circuit
Heights: 3"
Septum width: 7"

Frequency range: 700-910

Location: NBS field site, outside
Targets & depths: PM-60:1,2,6

Approximate date: 5/15/74
Soil moisture: 3%

Reference report: "Articulated Arrays", June 15, 1974

Comparison series: 74-3

Experiment: Coverage of 2 articulated (allows relative vertical movement of heads) arrays using 2 head designs: 790 SYH at 0 & 90 degrees, and 790 NSYH at 0 and 90.

Result: Not as good as 790 SYH. Lower response magnitude, large change with target depth, & would require more heads for given coverage.

Reference No: 55
Head: 790 SYH array
Head sketch No: 32

Dipole type: Adjustable cylindrical
Heights: 3"
Septum width: 6"
Frequency range: 610-910

Location: NBS field site, outside
Targets & depths: PM-60:1,2,6
Approximate date: 6/10/74
Soil moisture: 3%

Reference report: "Articulated Arrays", June 15, 1974
Comparison series: 74-3

Experiment: Test the effect of leaving a gap or split in the septum.

Result: Does not degrade performance.

Reference No: 56
Head: 790 SYH
Head sketch No: 33

Dipole type: Adjustable cylindrical
Heights: 1, 2, 3, 4, 5"
Septum width: 6"
Frequency range: 610-910

Location: NBS field site
Targets & depths: M-19: 1,3,5
Approximate date: 8/15/74
Soil moisture:

Reference report: "Microwave Holygraphy & Hardened Heads" 9/24/74
Comparison series: 74-4

Experiment: Test the effect of "hardening" the head: polyurethane foam fill (dielectric constant of approximately 1.03) and a 1/16" fiberglass cover.

Result: Reduced center frequency by 80 MHz, otherwise little change in performance, except slightly better coverage.

Reference No: 57
Head: 790 NSYH
Head sketch No:

Dipole type: Printed circuit
Heights: 1, 2, 3, 4, 5"
Septum width: 7"
Frequency range: 610-910

Location: NBS field site
Targets & depths: M-19: 1,3,5
Approximate date: 8/15/74
Soil moisture:

Reference report: "Microwave Holygraphy & Hardened Heads" 9/24/74
Comparison series: 74-4

Experiment: Test the effect or "hardening" the head: polyurethane foam fill (dielectric constant of approximately 1.03) and a 1/16" fiberglass cover.

Result: Reduced center frequency by 30 MHz, otherwise no significant change in performance, including coverage.

Reference No: 58
Head: S band horn | Head sketch No:

Dipole type: N.A. | Frequency range: 2.5, 2.9
Heights: 4 +/- 1/8"
Septum width: N.A.

Location: NBS field site, inside | Approximate date: 7/20/74
Targets & depths: PM-60:1; TMDB:1,3; M-19:1,3,5 | Soil moisture: 1 - 6%

Reference report: "Microwave Holygraphy & Hardened Heads" 9/24/74 | Comparison series: 74-5

Experiment: Data taken for test of holographic imaging by General Dynamics. Head run 4" high, grid scan in 1" increments each direction over 6 targets.

Result: Controlling random phase fluctuation is difficult. In spite of this, the contractor was able to use the data to form reasonable images.

Reference No: 59
Head: 790 SYH dielectric loaded | Head sketch No: 34,35,36

Dipole type: Cylindrical | Frequency range: 670-850
Heights: 2, 3, 4"
Septum width: 5, 6, 7"

Location: NBS field site, inside | Approximate date: 7/30/74
Targets & depths: PM-60: 1,2,6 | Soil moisture: Low

Reference report: Progress Report, Jul - Sept, 1974 | Comparison series: 74-6

Experiment: Tests on heads filled with dielectric materaial, including: lucite, paraffin, hi K (4) foam, lo K (1.03) foam, & water.

Result: Did slightly improve coverage performance. Problems: weight, restricted operating height, decreased response. Very low K foam: minimum problems with some performance improvement. Recommend using it.

Reference No: 60
Head: 900 SYH | Head sketch No: 37

Dipole type: Cylindrical | Frequency range:
Heights: 2, 3, 4"
Septum width: 6"

Location: NBS field site, inside | Approximate date: 8/10/74
Targets & depths: PM-60: 1,2,6 | Soil moisture: Low

Reference report: Progress Report, Jul - Sept, 1974 | Comparison series: 74-7

Experiment: Test of head design to be used with hand-held detector.

Result: Restricted operating height, but also detects smaller and more shallow targets. Good compromise when head is used to pinpoint antitank mines and detect antipersonnel mines.

Reference No: 61
Head: 1 GHz SYH
Head sketch No: 38

Dipole type: Cylindrical
Heights: 2, 3, 4"
Septum width: 5"
Frequency range: 850-1150

Location: NBS field site, inside
Targets & depths: PMN-6
Approximate date: 9/10/74
Soil moisture: Low

Reference report: Progress Report, Jul - Sept, 1974
Comparison series: 74-7

Experiment: Test of head design to be used with hand-held detector, especially for antipersonnel mines.

Result: Best for antipersonnel mines. Best 1 to 2" high. Does not work so well for larger targets.

Reference No: 62
Head: 790 SYH array
Head sketch No: 39

Dipole type: Cylindrical
Heights: 3"
Septum width: 6, 7, 7.5"
Frequency range: 850-1150

Location: NBS field site, inside
Targets & depths: PM-60: 1,2,6
Approximate date: 11/15/74
Soil moisture: Low

Reference report: Progress Report, Oct - Dec, 1974
Comparison series: 74-8

Experiment: Further coverage tests using articulated split septum arrangement in single and double row arrays. Also tried no septum (array of reflectors only).

Result: Arrays run at 90 degrees with septum gaps (location of gap not critical) works well. Coverage not adequate with a single row, but is with two.

Reference No: 63
Head: 790 NSYH
Head sketch No: 30

Dipole type: Printed circuit
Heights: 3"
Septum width:
Frequency range: 610-910

Location: NBS field site, inside
Targets & depths: PM-60: 1,2,6
Approximate date: 11/1/74
Soil moisture: 5 - 1%

Reference report: Progress Report, Oct - Dec, 1974
Comparison series: 74-9

Experiment: Periodic zero-offset "control" measurements as a function of moisture content (over period of 3 months).

Result: Documents an erratic wet soil behaviour noted in the nonsymmetrical head, especially occurring right after a rain shower (or other wetting of the soil).

Reference No: 64
Head: 1 GHz SYH

Head sketch No: 40,44

Dipole type: Cylindrical
Heights: 3, 4"
Septum width: 4, 5, 6"

Frequency range: 920-1100

Location: NBS field site, inside
Targets & depths: PM-60: 1,6

Approximate date: 3/15/75
Soil moisture: 4.5 - 16%

Reference report: Progress Report, Apr-Jun, 1975, "Wet Soil Measurements"

Comparison series: 75-1

Experiment: A comparison of 4 heads (1GHz SYH, 900 SYH, 790 SYH, & 790 NSYH) in wet (15-12%), intermediate (12-8%), & dry (8%) conditions. Tested optimum septum width & "fin".

Result: Superior to all others in wet conditions. Unique in detecting targets under 1" of water. Optimum septum width 1" wider dry than wet. Worst for 6" deep target at intermediate and dry conditions. 1" Fin little help.

Reference No: 65
Head: 900 SYH

Head sketch No: 41

Dipole type: Cylindrical
Heights: 3, 4"
Septum width: 4, 5, 6"

Frequency range: 820-1000

Location: NBS field site, inside
Targets & depths: PM-60: 1,6

Approximate date: 3/15/75
Soil moisture: 4.5 - 16%

Reference report: Progress Report, Apr-Jun, 1975, "Wet Soil Measurements"

Comparison series: 75-1

Experiment: A comparison of 4 heads (1GHz SYH, 900 SYH, 790 SYH, & 790 NSYH) in wet (15-12%), intermediate (12-8%), & dry (8%) conditions. Looked for optimum septum width.

Result: Did have the best response for 1" deep target with intermediate moisture, but missed it under wet conditions. Otherwise, generally average. Optimum septum width, 1 to 2" wider dry than wet.

Reference No: 66
Head: 790 SYH

Head sketch No: 42,45

Dipole type: Cylindrical
Heights: 3, 4"
Septum width: 4, 5, 6"

Frequency range: 680-860

Location: NBS field site, inside
Targets & depths: PM-60: 1,6

Approximate date: 3/15/75
Soil moisture: 4.5 - 16%

Reference report: Progress Report, Apr-Jun, 1975, "Wet Soil Measurements"

Comparison series: 75-1

Experiment: A comparison of 4 heads (1GHz SYH, 900 SYH, 790 SYH, & 790 NSYH) in wet (15-12%), intermediate (12-8%), & dry (8%) conditions. Tested septum width and "fin".

Result: Did have the best response for 6" deep target with intermediate moisture, with average performance rest of the time. Optimum septum width 2" wider dry than wet. 1" Fin little help.

Reference No: 67
Head: 790 NSYH
Head sketch No: 43

Dipole type: Printed circuit
Frequency range: 680-860
Heights: 3, 4"
Septum width: 4, 5, 6, 7"

Location: NBS field site, inside
Approximate date: 3/15/75
Targets & depths: PM-60: 1,6
Soil moisture: 4.5 - 16%

Reference report: Progress Report, Apr-Jun, 1975, "Wet Soil Measurements"
Comparison series: 75-1

Experiment: A comparison of 4 heads (1GHz SYH, 900 SYH, 790 SYH, & 790 NSYH) in wet (15-12%), intermediate (12-8%), & dry (8%) conditions. Looked for optimum septum width.

Result: Usually, had the poorest response under wet conditions for any depth target. Otherwise, about average performance. Optimum septum width is 1 to 3" wider dry than wet, depending on target depth.

Reference No: 68
Head: 1 GHz SYH
Head sketch No: 46

Dipole type: Cylindrical
Frequency range: 880-1060
Heights: 2, 3, 4"
Septum width: 1,2,3,4,5,6,7,8

Location: NBS field site, inside
Approximate date: 11/15/75
Targets & depths: PM-60: 1,6
Soil moisture: 13.6%

Reference report: Report: Oct-Dec, 1975, "Wet Soil Measurements II"
Comparison series: 75-2

Experiment: A comparison of 2 heads (1 GHz SYH, & 790 SYH) as a function of septum width and head height in wet soil.

Result: Within it's operating height constraint (3"), the 1 GHz head is best in these wet conditions, especially for the shallow target. Optimum septum width increases with height and target depth.

Reference No: 69
Head: 790 SYH
Head sketch No: 47

Dipole type: Cylindrical
Frequency range: 680-860
Heights: 2, 3, 4"
Septum width: 1,2,3,4,5,6"

Location: NBS field site, inside
Approximate date: 11/15/75
Targets & depths: PM-60: 1,6
Soil moisture: 13.6% avg.

Reference report: Report: Oct-Dec, 1975, "Wet Soil Measurements II"
Comparison series: 75-2

Experiment: A comparison of 2 heads (1 GHz SYH, & 790 SYH) as a function of septum width and head height in wet soil.

Result: Main advantage is an operating height of at least 4 inches. A decrease in septum width has brought it closer to the 1 GHz head wet performance, especially for the deep target.

Reference No: 70
Head: 900 SYH
Head sketch No: 41

Dipole type: Cylindrical
Heights: 2, 3, 4"
Septum width:
Frequency range: 820-1000

Location: NBS field site, inside
Targets & depths: PM-60: 1,6
Approximate date: 12/15/75
Soil moisture: 8.6%

Reference report: Report: Oct-Dec, 1975, "Wet Soil Measurements II"
Comparison series: 75-3

Experiment: Determine the effect of 3/4" split in septum at edge of one of the reflectors.

Result: Insignificant decrease in the response of the split septum configuration as compared to a solid septum.

Reference No: 71
Head: Ridged waveguide horns
Head sketch No: 48

Dipole type: NA
Heights: 0.5, 3"
Septum width: 2"
Frequency range: 1360-1580

Location: NBS field site, inside
Targets & depths: PM-60:1,6; AP:0.5
Approximate date: 11/20/75
Soil moisture:

Reference report: Report: Oct-Dec, 1975, "Wet Soil Measurements II"
Comparison series: 75-4

Experiment: Investigation of using ridged waveguide horns in the separated aperature mode.

Result: Did not work well; best response was obtained with the horns cross polarized and run at 45 degrees to the direction of travel. Did detect the small, shallow antipersonnel mine, which no other head has done.

Reference No: 72
Head: 1 GHz SYH
Head sketch No: 49

Dipole type: Cylindrical
Heights: 1, 2, 3"
Septum width: 1, 2, 3"
Frequency range: 880-1060

Location: NBS field site, inside
Targets & depths: PMN-6:0.5; NBS-AP:1; PM-60:1
Approximate date: 1/15/76
Soil moisture: 3 - 6%

Reference report: Progress Report, Jan-Mar, 1976, "AP Mine Detection"
Comparison series: 76-1

Experiment: Development of a symmetrical head that can detect antipersonnel mines. Comparison of two heads (1 GHz SYH & a new 1.2 GHz SYH) vs various modifications.

Result: Even modified, not as good as the 1.2 GHz head. This is not surprising, since the 1 GHz head is larger.

Reference No: 73
Head: 1.2 GHz SYH

Head sketch No: 50

Dipole type: Cylindrical
Heights: 1, 2, 3"
Septum width: 1, 2, 3"

Frequency range: 1120-1300

Location: NBS field site, inside
Targets & depths: PMN-6:0.5; NBS-AP:1; PM-60:1

Approximate date: 1/15/76
Soil moisture: 3 - 6%

Reference report: Progress Report, Jan-Mar, 1976, "AP Mine Detection"

Comparison series: 76-1

Experiment: Development of a symmetrical head that can detect antipersonnel mines. Comparison of two heads (1 GHz SYH & a new 1.2 GHz SYH) vs various modifications.

Result: With a 2" septum, has the best response to the AP targets. To work above 2" high it requires a vertical conducting barrier (flexible "fin" or "wiper") attached to the septum between the reflectors. Needs more work.

Reference No: 74
Head: 790 SYH

Head sketch No: 47

Dipole type: Cylindrical
Heights: 2, 4"
Septum width:

Frequency range:

Location: NBS field site, inside & outside
Targets & depths: PM-60:1,6"

Approximate date: 3/29/77
Soil moisture: 2 - 14%

Reference report: "Measurement Report" 8/1/79

Comparison series: 77-1

Experiment: Compares the wet/dry performance vs height & offset of the 790 SYH containing cylindrical dipoles with it containing printed circuit dipoles.

Result: In wet soil conditions, the tubular dipoles perform significantly better than the pc dipoles. They both respond about the same in dry soil, except for the deep target at 4" high and zero offset where the pc dipoles are better.

Reference No: 75
Head: 790 SYH

Head sketch No: 47

Dipole type: Printed circuit
Heights: 2, 4"
Septum width:

Frequency range:

Location: NBS field site, inside & outside
Targets & depths: PM-60:1,6"

Approximate date: 3/29/77
Soil moisture: 2 - 14%

Reference report: "Measurement Report" 8/1/79

Comparison series: 77-1

Experiment: Compares the wet/dry performance vs height & offset of the 790 SYH containing cylindrical dipoles with it containing printed circuit dipoles.

Result: The pc dipoles are generally inferior in response amplitude, especially in wet soil conditions. They both respond about the same in dry soil, except for the deep target at 4" high and zero offset where the pc dipoles are better.

Reference No: 76
Head: PRM-8 antenna for antipersonnel mine detector

Head sketch No:

Dipole type: Balanced bridge antenna
Heights: 1, 2"
Septum width: NA

Frequency range: 300-1400

Location: NBS field site, indoor & outdoor
Targets & depths: PM-60:?; PMN-6:?; M14:?; M25:?; M16:?

Approximate date: 7/24/79
Soil moisture: 8 - 23%

Reference report: "Measurements Report, PRM8 Antenna" 1979

Comparison series: 79-1

Experiment: Tests of the antenna over several antipersonnel mine targets under wet and dry conditions.

Result: The antenna did work reasonably well, detecting the small targets under both the dry & wet conditions better than any previously tested antenna. It does need to be kept close to the ground (< 1" high).

APPENDIX C. TARGET AMPLITUDE DESCRIPTOR

Most of the results given in the reports are based on a data processing algorithm called the Target Amplitude Descriptor (TAD) which is the logarithm of a target-to-background ratio. Explicitly, it is given by the expression:

$$TAD_i = 20 \log\left(\frac{1}{n} \sum_{j=i}^{n} \frac{A_{ij}}{B_{ij}}\right)$$

where,

A_{ij} = the value of amplitude data for position i and frequency j,

B_{ij} = an exponentially smoothed background estimate for position i and frequency j,

and

n = total number of frequencies measured.

B_{ij} is determined by:

$$B_{ij} = B_{i-1,j}\ (1-a_2) + \alpha_2\ A_{i-1,j}$$

where,

$$\alpha_2 = \alpha_1;\ \text{if } ASUM_i \leq 0.9$$
$$0;\ \text{otherwise}$$

$$\alpha_1 = 1 - e^{-2\Delta Xi/DECAY},$$

ΔX_i = position increment between the samples at i and i-1

and

DECAY = the distance prior to position i where the relative weight of the contribution to the background estimate is down 13%.

For most of the measurements, ΔX_i = 2 inches and DECAY = 40 inches.

ASUM (Average) is another form of data processing used; it is the average of the target to background difference which has been weighted by the standard deviation of the background. ASUM is very effective as a target indicator, in fact, better than TAD, but not for making objective numerical comparisons. It is given by:

$$ASUM_i = \frac{1}{n} \sum_{j=1}^{n} An_{ij}$$

where,

$$An_{ij} = \frac{A_{ij} - B_{ij}}{\sigma_{ij}}$$

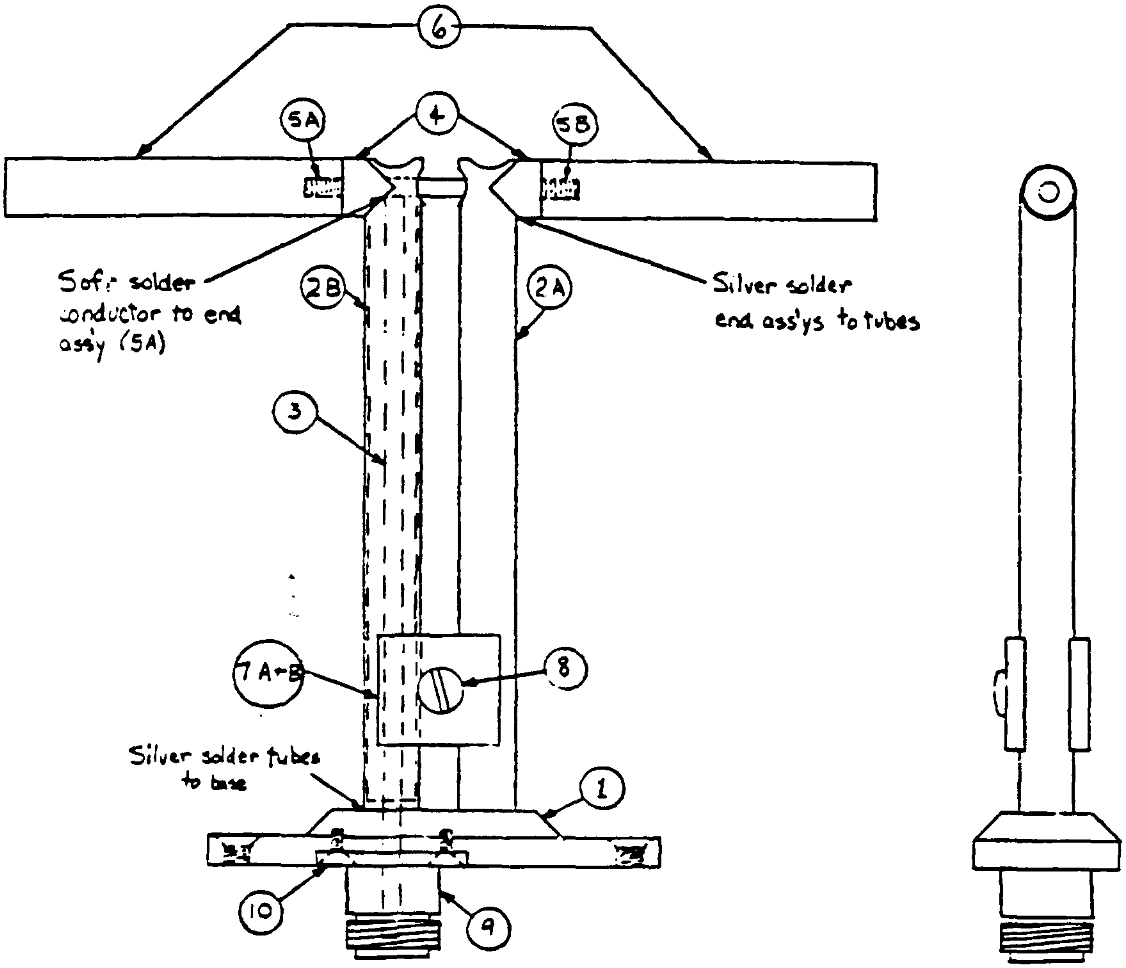
A_{ij} and B_{ij} have previously been defined and

$$\sigma_{ij2} = (\sigma_{i-1,j})^2(1-\alpha) + \alpha(A_{i-1,j} - B_{i-1,j})^2$$

For each run it is necessary to select or determine an initial value for B and σ.

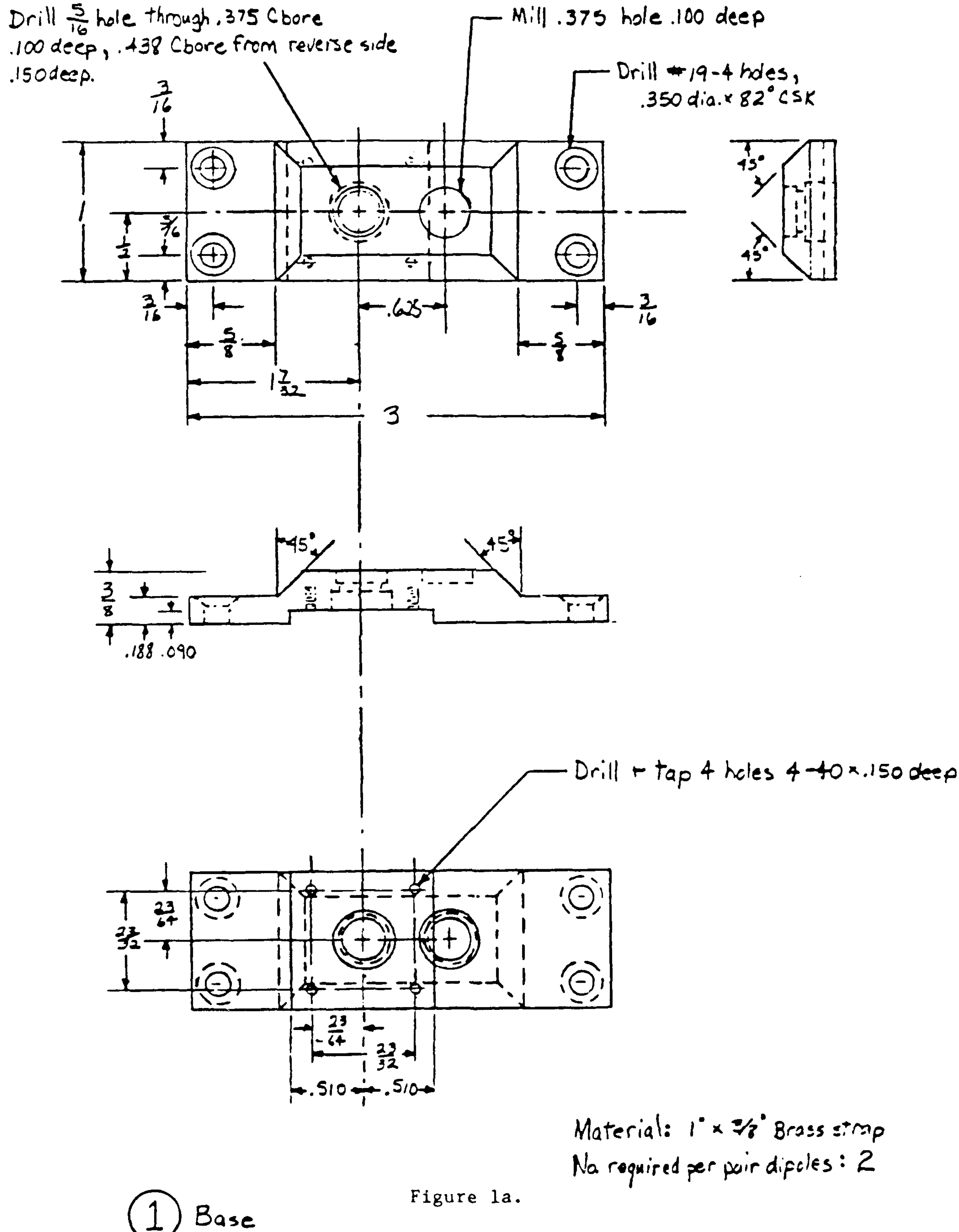
APPENDIX D. DIPOLE DRAWINGS

This appendix contains copies of the original drawings for the tubular dipole used in the 790 symmetrical head and the sheetmetal layout for the reflector. As indicated, to operate at a different frequency the element length and position of the short are changed. Those dimensions can be scaled based on the wavelength at the desired operating frequency.



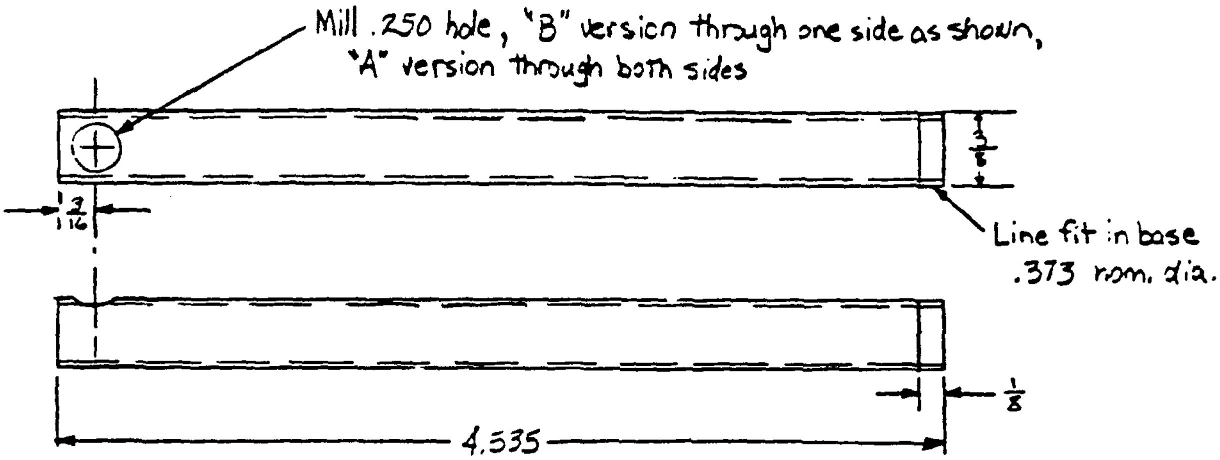
1 Base
2 Tubes
3 Center conductor
4 Transition
5 End
6 Element
7 Short
8 8-32 x 5/8" Binding head mach. screw
9 Connector
10 4-40 x 3/16" Flat head mach. screw

Figure 1. Drawing of the dipole used in the 790 MHz symmetrical head. For use at other frequencies the length of the elements 6 and the position of short 7 must be changed.



Drill 5/16 hole through .375 Cbore .100 deep, .438 Cbore from reverse side .150 deep.
Mill .375 hole .100 deep
Drill #19-4 holes, .350 dia. x 82° CSK
3/16
3/16
1/2
45°
45°
3/16
5/8
.625
3/16
5/8
1 7/32
3
45°
45°
3/8
.188 .090
Drill + tap 4 holes 4-40 x .150 deep
23/64
23/32
23/64
23/32
.510
.510
Material: 1" x 3/8" Brass strip
No. required per pair dipoles: 2
1 Base

Figure 1a.

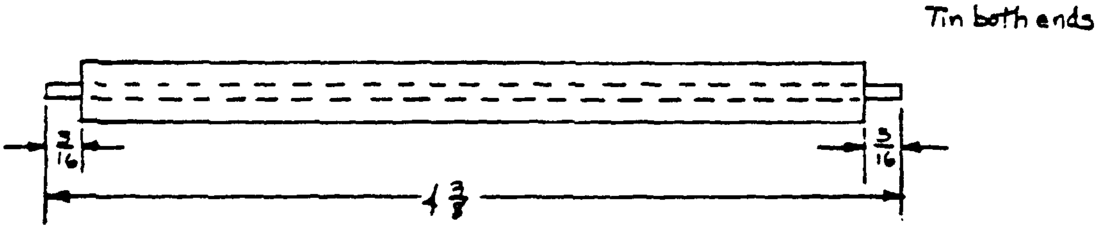


Notes: Length arbitrary and chosen to fit height of desired reflector

Material: 3/8 x .035 wall brass tube

No. required per pair dipoles: A – 2
B – 2

(2) Tube

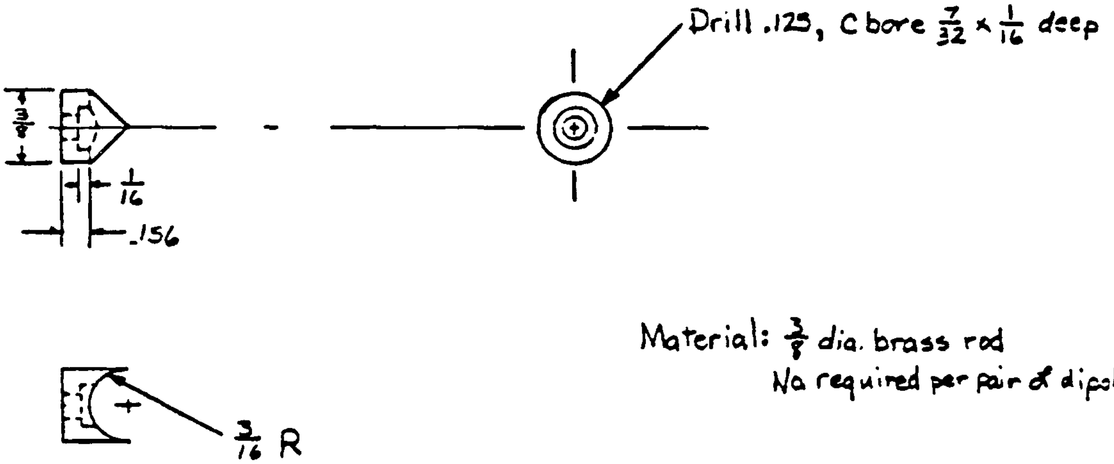


Material: RG-8 Coaxial cable with outer cover and braid removed

No. required per pair of dipoles: 2

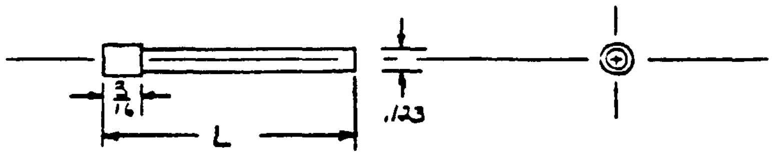
(3) Center Conductor

Figure 1b.



Material: $\frac{3}{8}$ dia. brass rod
No required per pair of dipoles : 4

(4) Transition

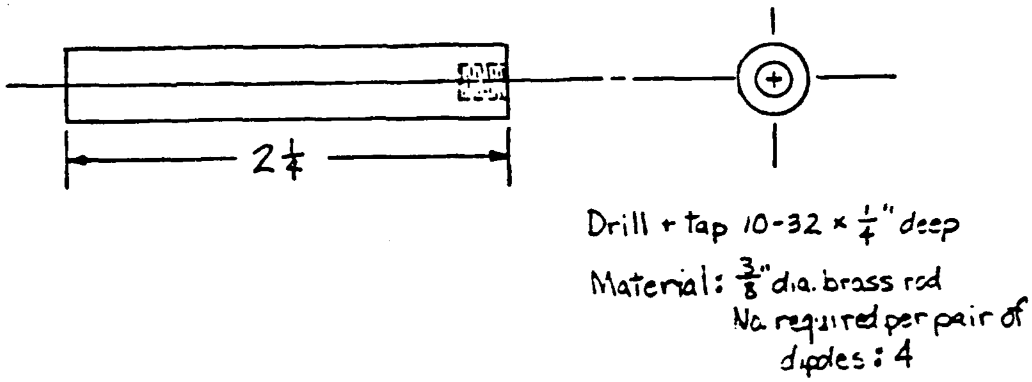


Part	Length "L"
5A	$1\frac{3}{32}$
5B	$\frac{5}{16}$

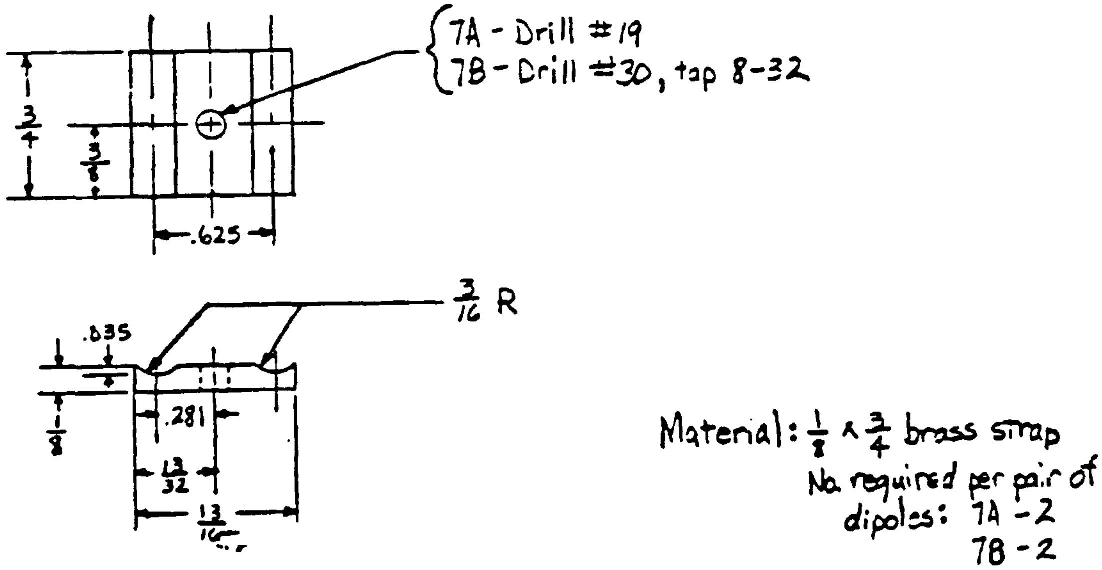
Material: 10-32 brass threaded rod
No. required per pair of dipoles:
5A - 2
5B - 2

(5) End

Figure 1c.



(6) Element



(7) Short

Figure 1d.

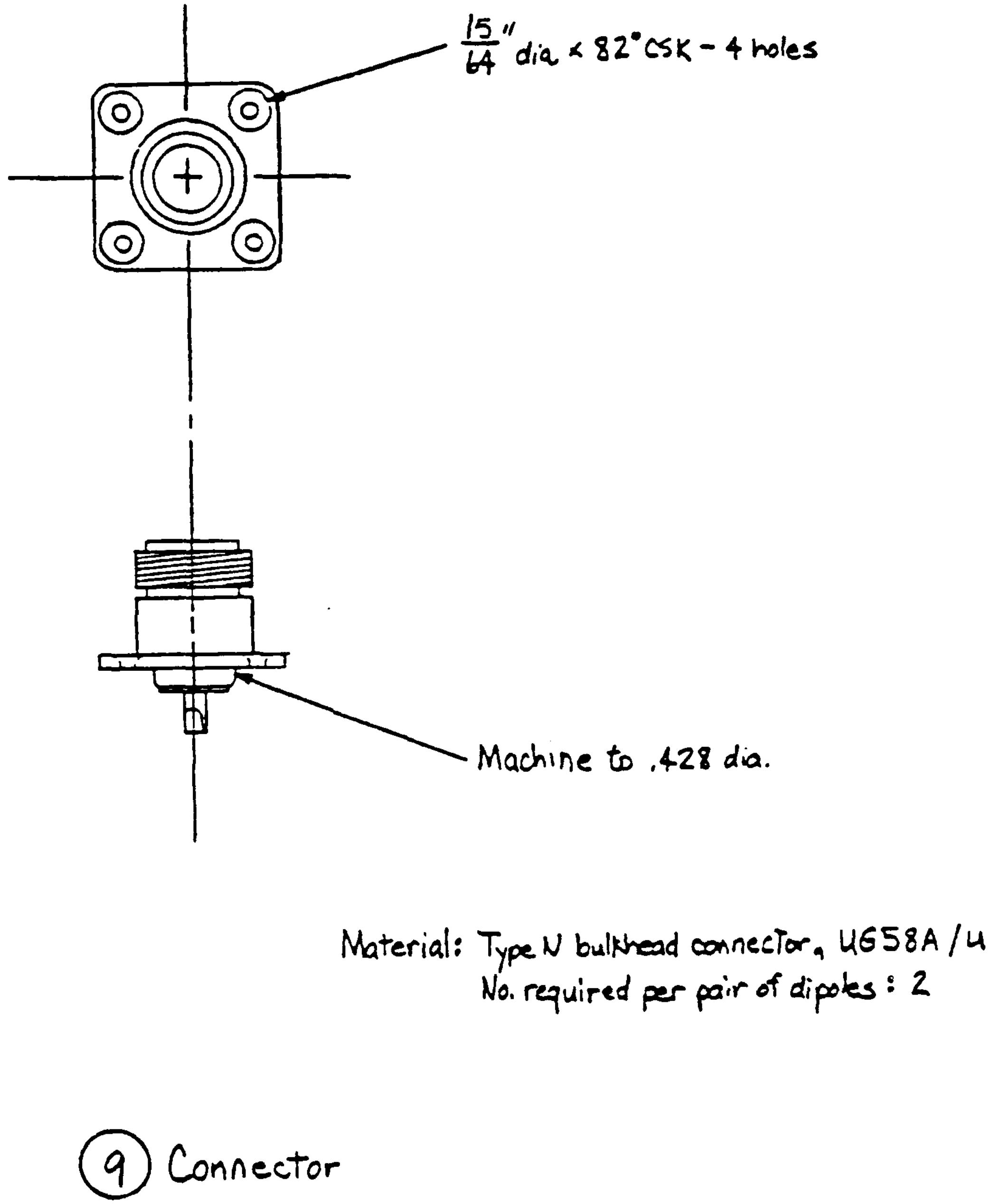

15/64" dia × 82° CSK - 4 holes
Machine to .428 dia.
Material: Type N bulkhead connector, UG58A/U
No. required per pair of dipoles: 2
9 Connector

Figure 1e.

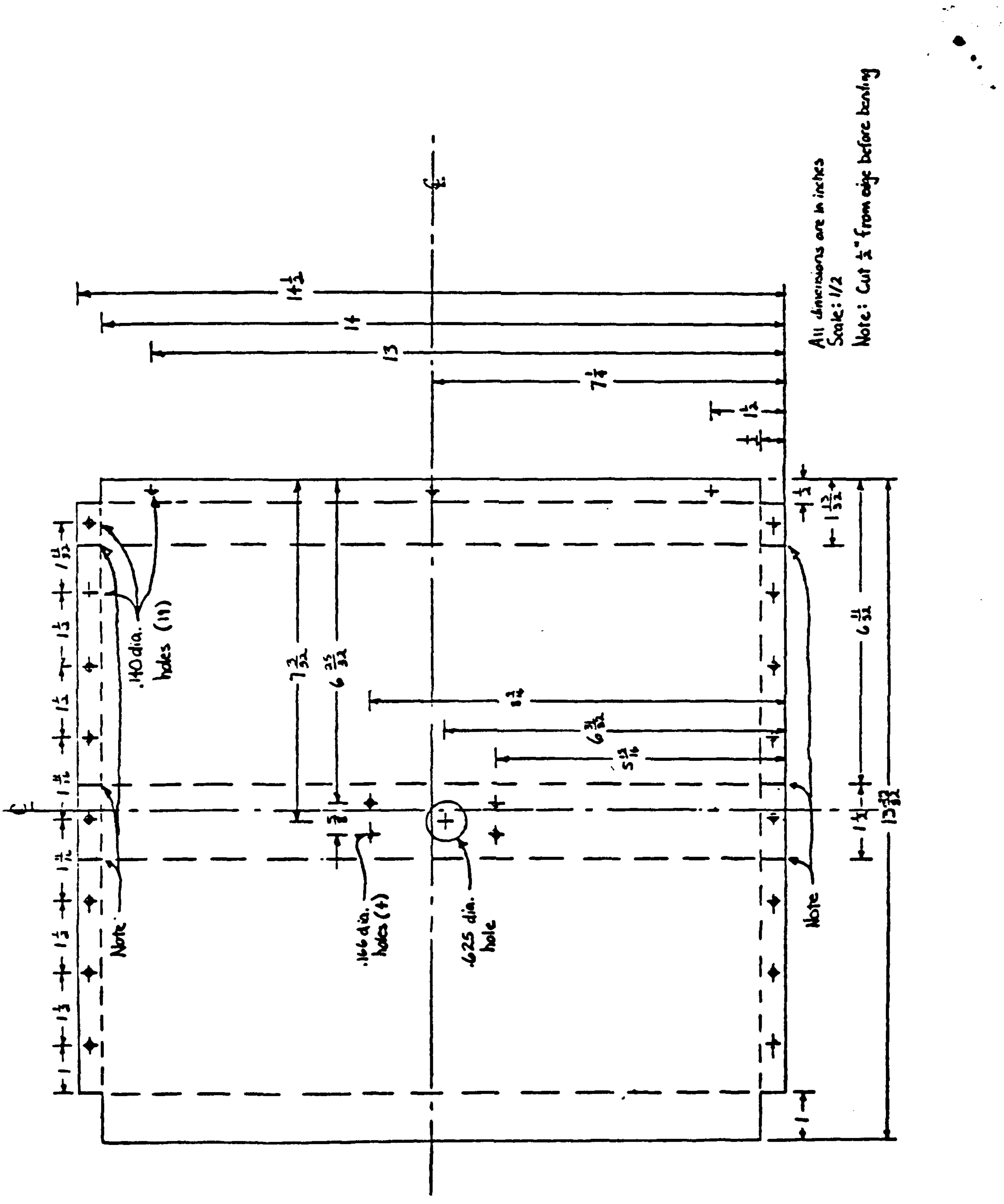


Figure 2. Sheet metal layout for the reflector of the 790 MHz Symmetrical Head.