THE 20th NATIONAL ELECTRONICS CONFERENCE
SEMINAR ON

TOPICS IN MODERN ANTENNA THEORY

A. FREQUENCY INDEPENDENT ANTENNAS—

V. H. Rumsey, University of California, *"Frequency Independent Antennas"*

P. E. Mayes, University of Illinois, *"Some Recent Results in Frequency Independent Antenna Research"*

B. ARRAY THEORY

A. Ishimaru, University of Washington, *"Recent Advances in Antenna Theory—Unequally Spaced Arrays"*

A. L. Maffett, Conductron Corporation, *"Application of Some Techniques of Numerical Analysis to the Theory of Nonuniform Arrays"*

C. DATA-PROCESSING ANTENNAS

A. Ksienski, Hughes Aircraft Company, *"Recent Advances in Signal Processing Systems"*

Session Chairmen: R. E. Hiatt, University of Michigan
M. A. Plonus, Northwestern University

McCormick Place
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Chicago, Illinois

SOME RECENT RESULTS IN FREQUENCY INDEPENDENT ANTENNA RESEARCH

P. E. Mayes*

I. EARLY WORK

An antenna is said to be frequency independent if the principal characteristics (radiation pattern and input impedance) change negligibly with frequency over a band which is limited only by the construction of the antenna and if the band can be readily extended by adding to the structure in a manner which is apparent from the structure geometry. This definition is designed to distinguish the frequency independent antenna from that which is loosely termed broad-band. The above definition serves to separate the log-spiral and log-periodic antennas from the so-called broad-band antennas of the past, such as the biconical and its flat counterpart, the bow-tie. However, it was from these early broad-band types which followed the angle concept as outlined by Professor V. H. Rumsey that the development of log-periodic antennas has proceeded.[1,2]

The troublesome thing about the bow-tie could be termed "end effect." For, although this shape of triangular fins would have frequency independent properties when extended to infinity, the truncation which is necessary in the practical antenna produces a length in the defining parameters and this length produces variations in the radiation pattern. DuHamel theorized that the end effect in a bow-tie might be eliminated if the energy could be removed by radiation in the region between feed point and truncation.[2] This reasoning led to the first successful log-periodic antennas, with a shape which is shown in Figure 1. The serrations were designed to produce the desired radiation. They were also designed to improve the chances that the resulting structure would be frequency independent. First, the shape is self-complementary; that is, if we consider the outlined region to be a flat sheet of conductor, the open region between the elements has a

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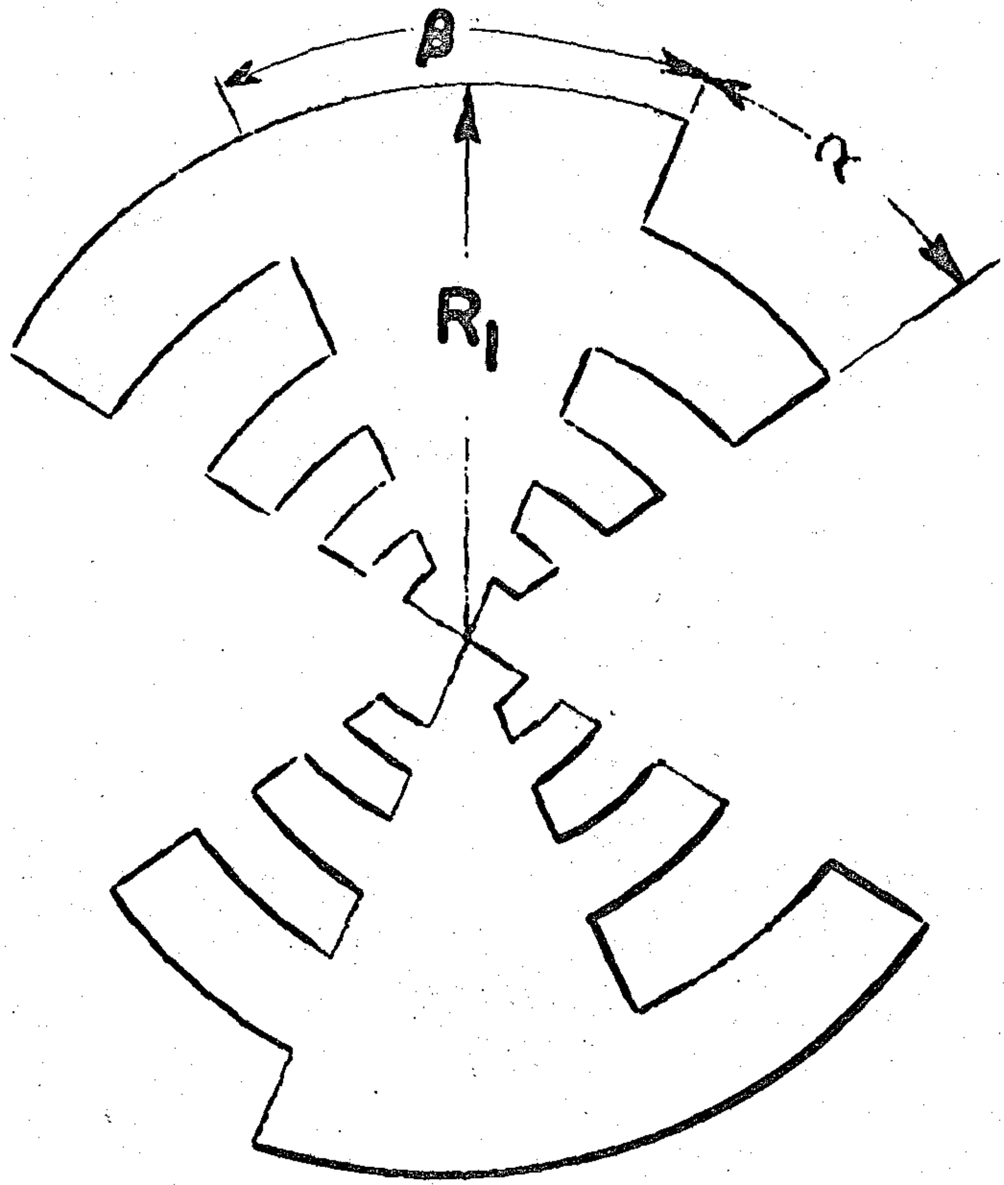

Figure 1. An early planar log-periodic structure.

shape which is identical to the shape of the conducting region. When such a self-complementary structure is infinite, Babinet's principle tells us that the input impedance is constant at 189 ohms regardless of the frequency. If the end effect is truly eliminated by the serrations, the antenna will appear infinite at the input terminals, and the impedance will be frequency independent. Although it was later found that this was not a necessary condition for frequency independent input impedance, it no doubt played an important part in the success of the first models.

The second general principle follows from similitude, which has been used for many years as a basis for testing antennas by using a scale model. The shape shown in Figure 1 is such that the application of a certain scale factor to this figure would result in the same figure except in the area near the truncation of the large and small ends of the structure. Hence, insofar as the truncations are unimportant to the antenna performance, the electrical characteristics of the antenna must be repeated at frequencies which are related by the scale factor, which is usually called τ. Since the same results could be obtained by many successive applications of the same scale factor (when the truncation effects are negligible), the performance should repeat at frequencies related by any integral power of the scale factor τ. This property of the geometry, that the electrical performance should repeat periodically with the logarithm of the frequency, was the motivation for the name "logarithmically periodic" or "log-periodic" structures.

The flat sheet metal antenna shown in Figure 1 produced a bi-directional beam which was linearly polarized with the electric vector parallel to the teeth. This latter observation confirmed that it was the currents flowing on the serrations which produced the radiation and the triangular fin merely acted as a transmission line to feed the radiating elements.

Important as they were, these first log-periodic antennas were not of great practical usefulness. The principal drawback was the bi-directional characteristic of the radiation which would naturally result from the symmetry of a planar structure. For most applications, a uni-directional radiation pattern is preferable. The obvious thing to try, then, is to spoil the symmetry of the structure in order to change the radiation pattern from a bi-directional one to a uni-directional one. Figure 2 shows a log-periodic antenna with elements tilted toward each other that was first investigated by Isbell.[3] It indicates that the desired uni-directional radiation was achieved, but, instead of radiating in the direction of phase progression of the current along the fin, the beam was produced in the opposite direction -- that is, toward the feed point. This "backfire" characteristic has been found to be inherent in the operation of most successful uni-directional frequency independent antennas and will be discussed further later.

The first development of wire outline versions of log-periodic antennas was done primarily by DuHamel and his co-workers at Collins Radio.[4,5] Figure 3 shows some of the modifications which were made to convert the first uni-directional log-periodic antennas into structures which would be practical for applications in the high frequency communications band -- 6 to 30 megacycles. Most of the conductor has been eliminated from the elements leaving only a central boom and the edges of the elements. The element shape has been changed from circular arc to straight line. The essential properties are retained, however, due to the common scale factor associated with the dimensions of any two adjacent elements.

Another very practical form of the antenna was developed by Isbell.[6] Although he proceeded along a different line of reasoning, the same result is achieved if we apply several perturbations to the antenna in Figure 3. If we let the element widths become small and then allow the angle between the planes of elements to go to zero, the result is the familiar log-periodic array of dipole elements shown in Figure 4. The perturbation just described leads naturally to the transposed feeder line shown in Figure 4.

Rumsey has pointed out the common symmetry properties in a self-complementary structure and the dipole array with transposed feeder.[1] It is interesting to note that the shape of the first log-periodic antennas was governed by a desire to obtain a self-complementary structure, and this dictated the staggered location of the "teeth" on the antenna shown in Figure 1. Although the perturbations in the structure of Figure 1 which lead to the dipole array of Figure 4 are rather severe, the symmetry is maintained through the use of the transposed feeder.

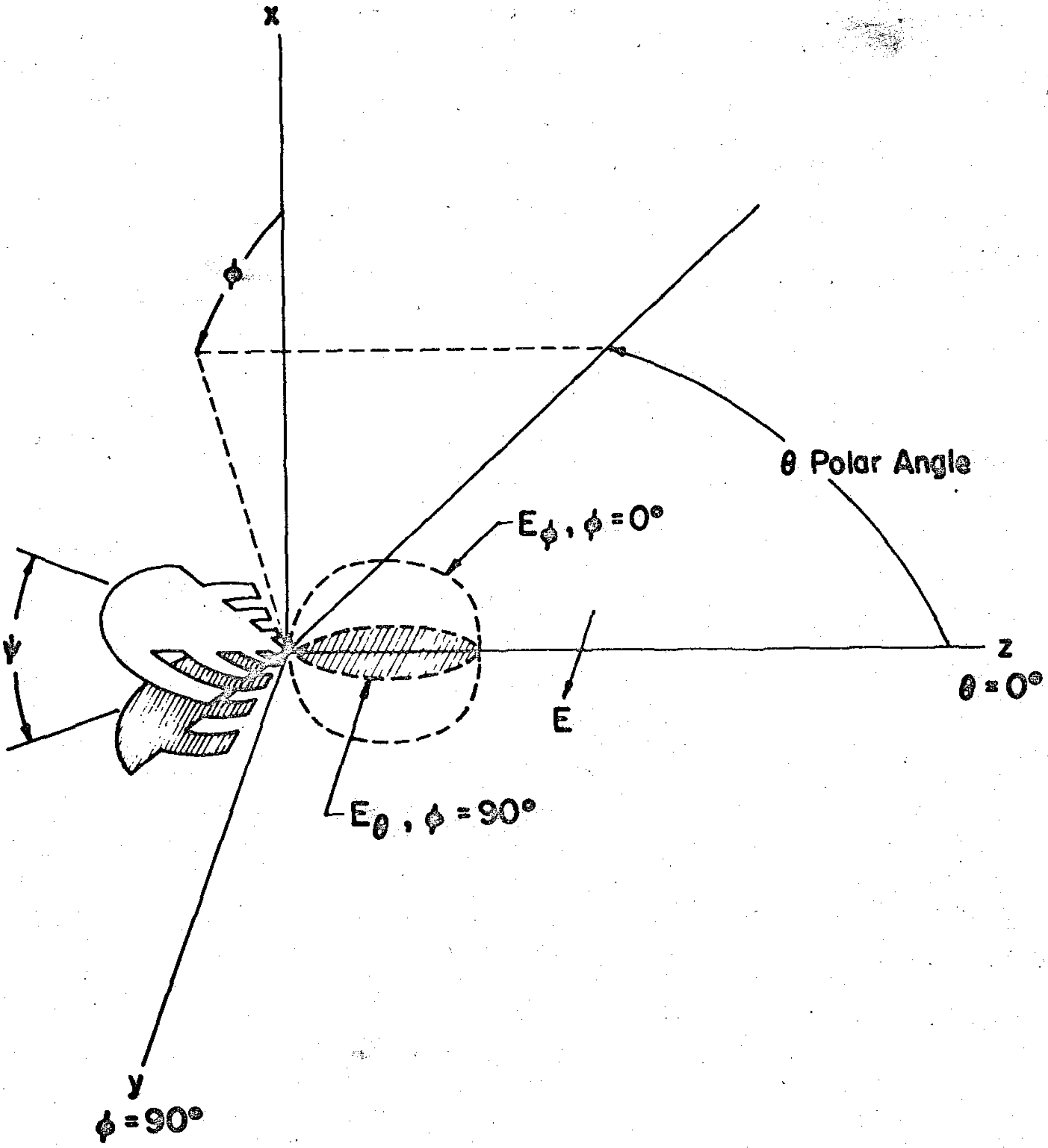

Figure 2. The first unidirectional log-periodic antenna showing the backfire beam.

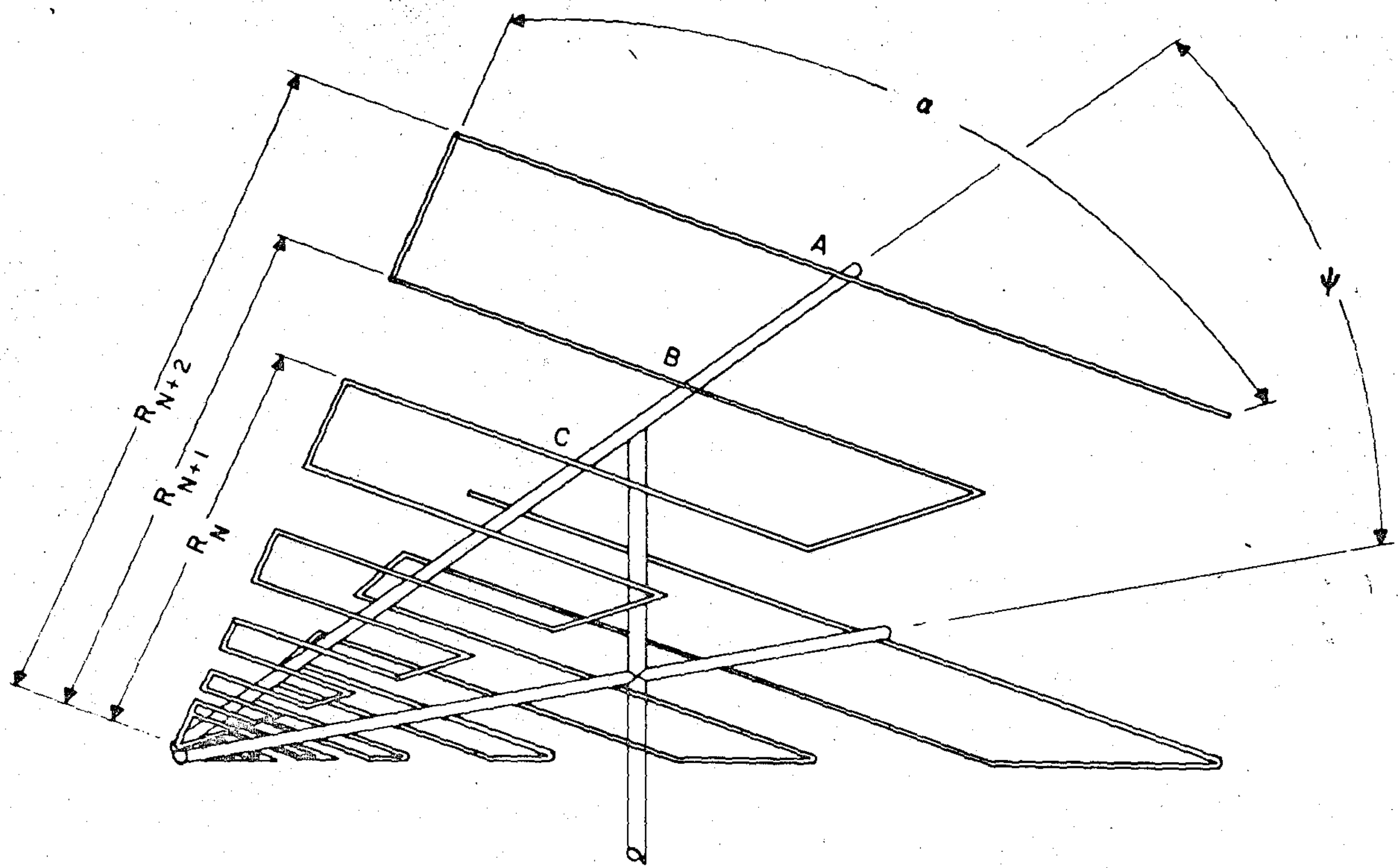

Figure 3. A wire-outline log-periodic antenna (Collins Radio Company).

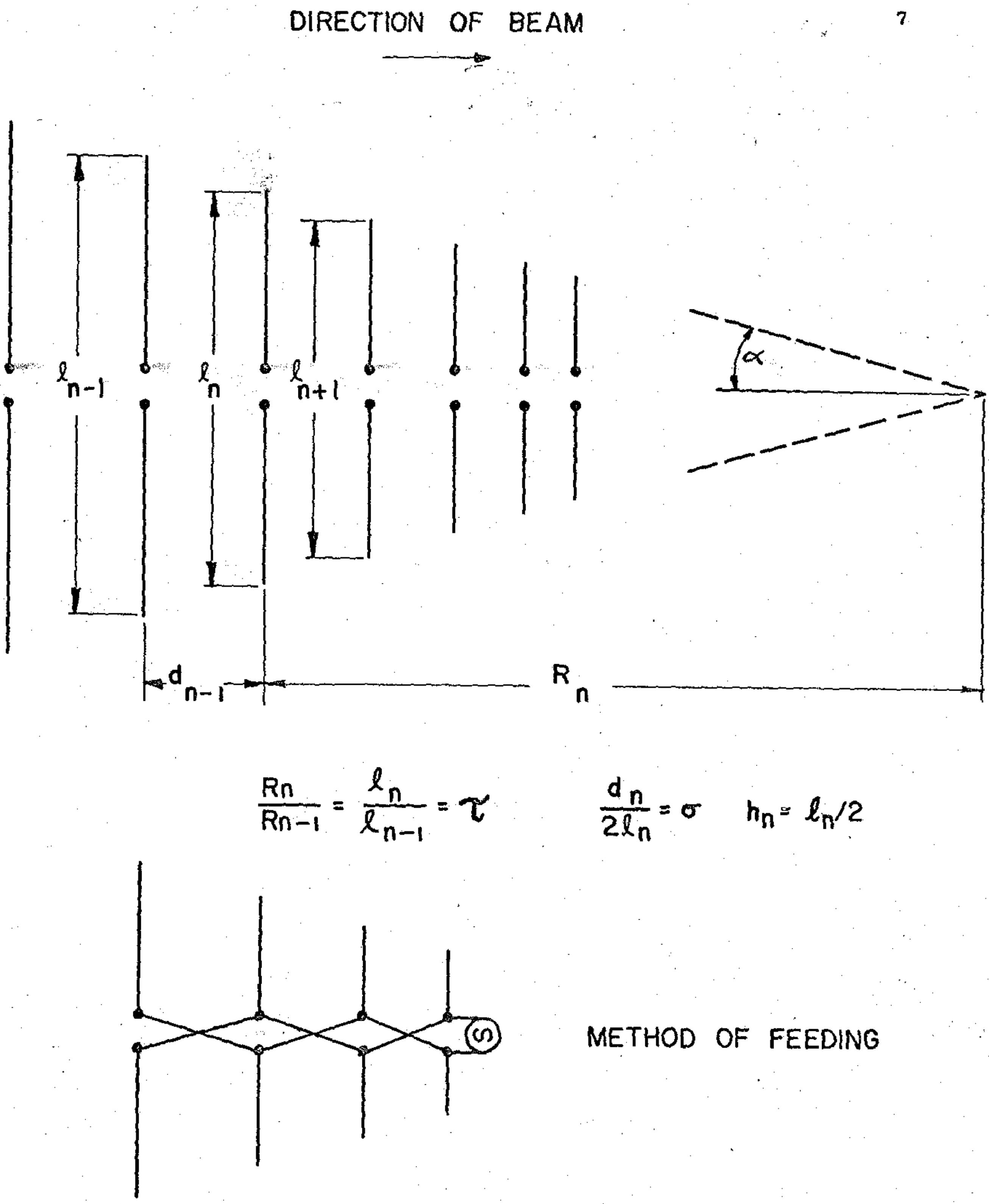

Figure 4. Schematic diagram of the log-periodic dipole array.

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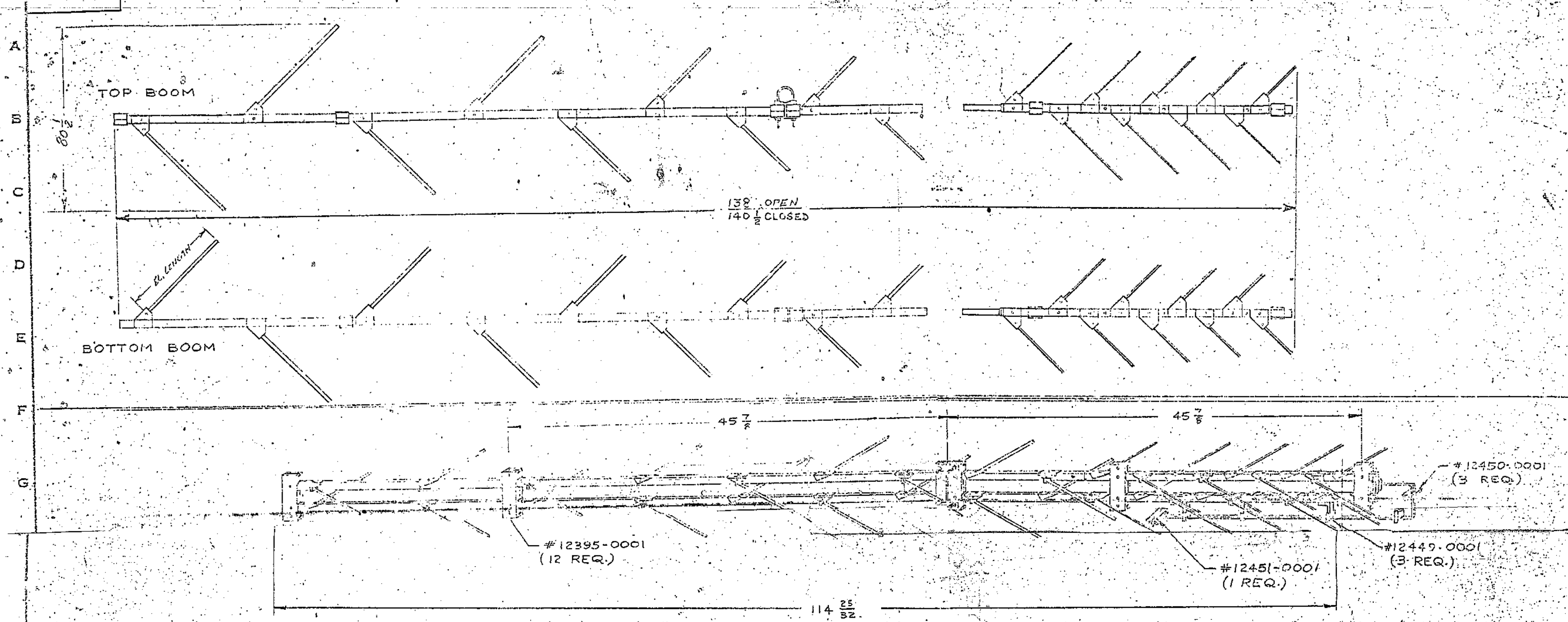

NOTE: BOOM BRACE PT# 11084-14 (CUT-SIZE $54\frac{1}{2}$)

CROSSARM LENGTH – $118\frac{1}{32}$

D-27

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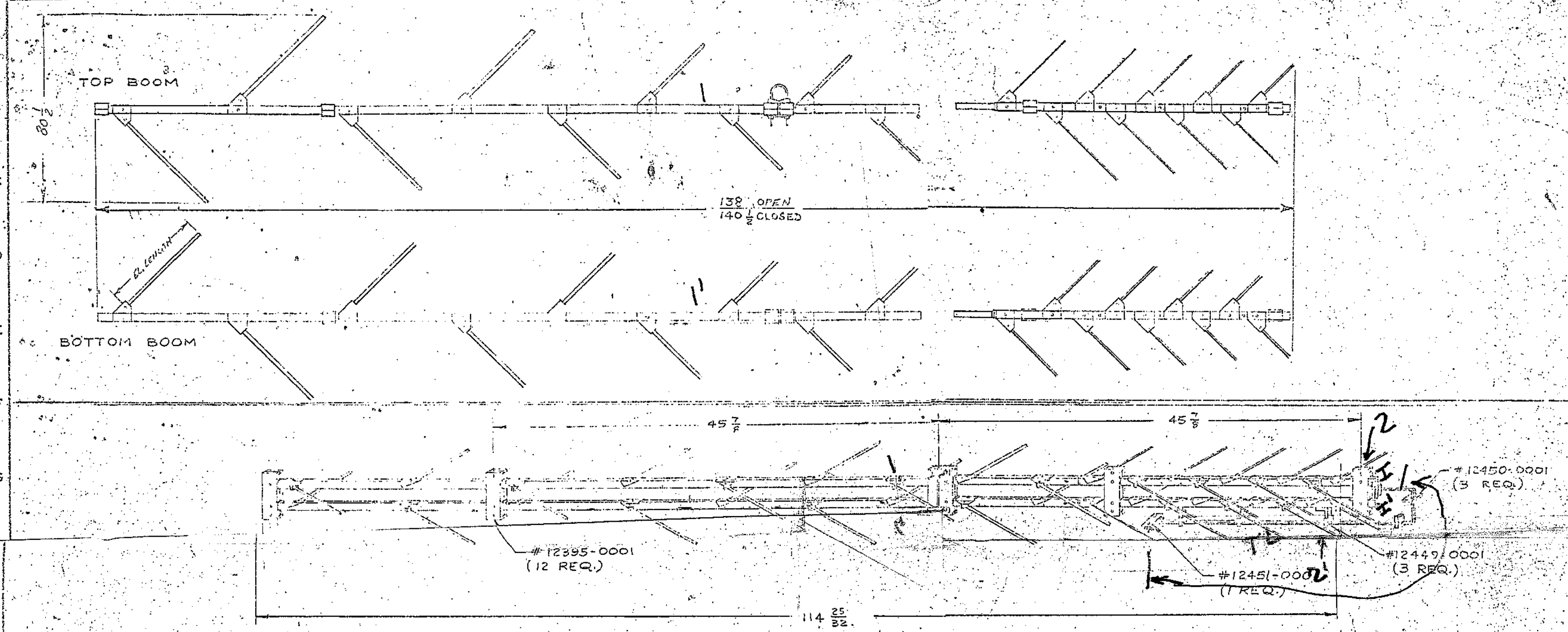

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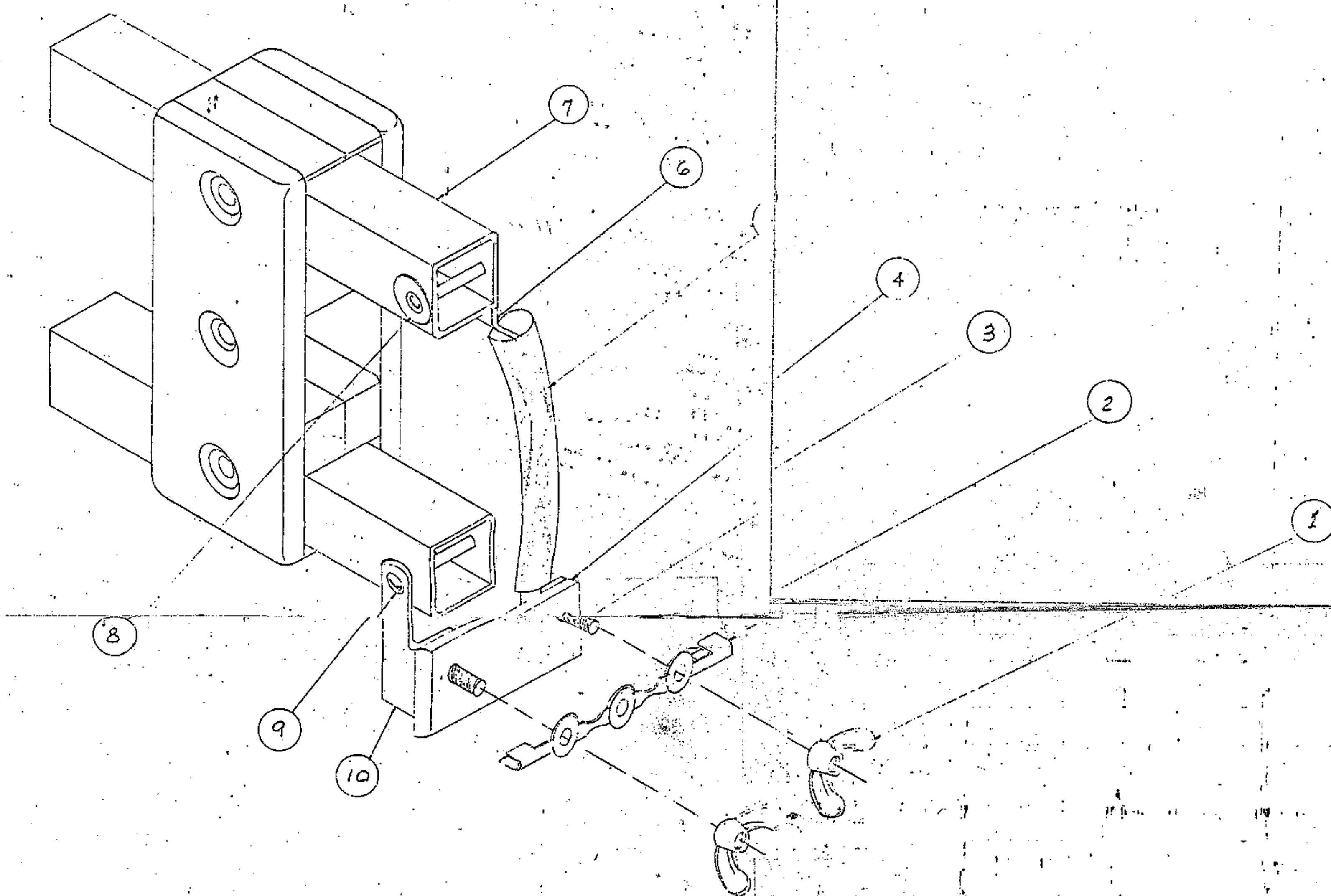

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8	2	12999-0301	WASHER 3/4 DIA x 1/16 WALL	ALUM	———	
7	2	———	CROSSARM 3/4 SQ x .035 WALL	ALUM	———	
6	1	13088-0001	TAKE OFF STRIP	ALUM	———	
5	1	12551-1301	MATHER SLEVE 3/8 ID x .025	VINYL	COLOR - BLACK	
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3	2	99151-0161	STUD RIVET # 10-32	STL	CAD & CHROMATE	
2	2	99455-0001	SOLDERLESS LUG # 10	COPPER	NICKLE PLATED	
1	2	99106-0201	WING NUT # 10-32	ZINC	———	

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