METHOD FOR PRECISION FORMING OF LOW-COST, THIN-WALLED SLOTTED WAVEGUIDE ARRAYS FOR THE SPS

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ABSTRACT

A method for the precision-forming of thin-walled, slotted-waveguide arrays has been devised. Models have been constructed with temporary tools and evaluated. The application of the method to the SPS requirements is discussed.

Introduction

The method for forming thin-walled slotted waveguide arrays that will be described grew out of a necessity to narrow down the broad range of estimated cost for slotted waveguide arrays in ground based arrays. In most items that are designed for automated production the cost of the material is the dominant element of cost. Therefore the use of thin material is attractive because of the large reduction in material cost. Then, if a rapid, inexpensive method of fabrication can be devised, the cost of the slotted waveguide arrays will be low and can be accurately estimated.

Such a fabrication method had been devised in principle by the author. An opportunity then arose to build working models of the design as part of a contract with JPL for the improvement of microwave beamed power technology, using a slight modification of their electrical design for such an array.

The working models that were made from 0.020 inch material were mechanically so strong and the fabrication technique so well adapted to even thinner material that the potential for a slotted waveguide array made from 0.005 inch or even thinner material for the SPS applications is very good.

Early estimates of the mass of a slotted waveguide array for the 1 kilometer diameter transmitting antenna for the SPS were based on the use of 0.020 inch thick aluminum material and these estimates may still persist and show up in current estimates of mass for the SPS. An array based on the use of 0.005 inch material in place of the 0.020 inch would save nearly 2.5×10^6 kilograms of material. Savings in transportation costs alone would be 250 million dollars if transportation costs were only \$100 per kilogram.

The fabrication of thin-walled guides can also be accomplished with great precision. Tolerances of ±2-3 mils should be possible.

Finally it appears, as shown in Figure 1, that the arrays can be relatively easily fabricated in space from rolls of aluminum foil which represents an ideal packing factor for transportation purposes.

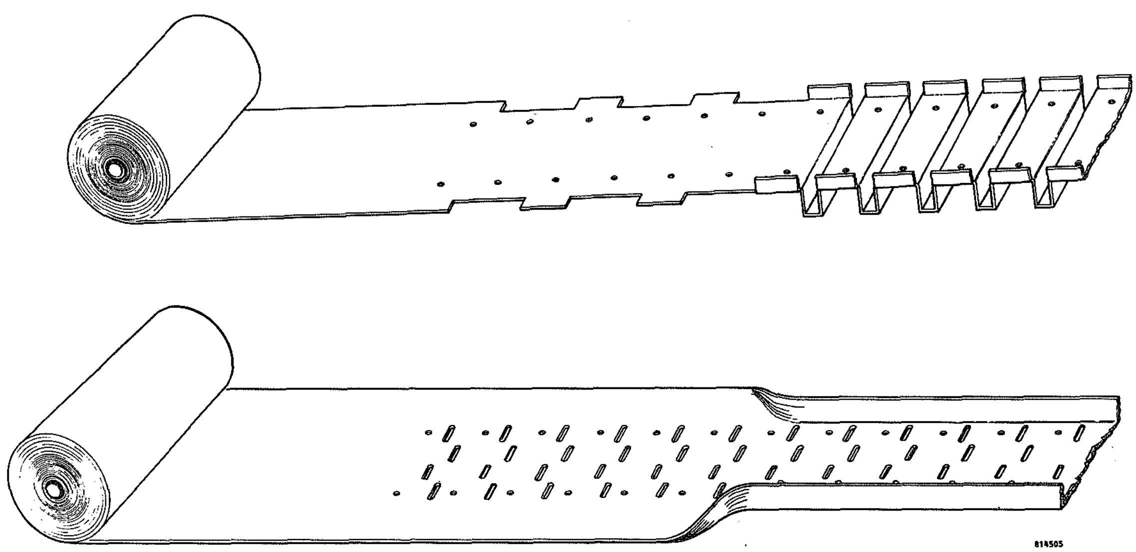

Figure 1. Proposed Method for Precision Forming and Assembly of Low-Cost, Thin-Walled, Slotted Waveguide Arrays for the SPS.

Description of Fabrication Method

The slotted waveguide array as shown in Figure 1 consists basically of a folded top plate whose corrugations contribute the three sides of the waveguide and a bottom plate into which the radiating slots are punched. The two sections then flow together and are joined to each other either by resistance spot welding or by laser beam welding to form the finished assembly shown in Figure 2.

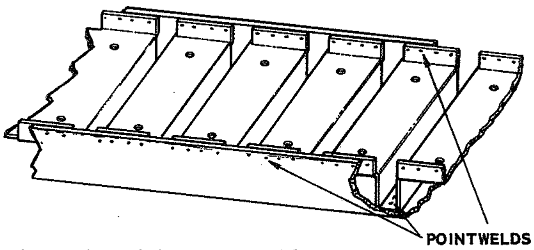

Figure 2. Finished Assembly.

The holes which are punched into the material are spaced accurately from each other and serve to accurately locate the material in the bending fixture which is also accurately machined and ground. The holes also serve to jig the top and bottom halves to each other for accurate assembly.

The method as originally proposed by the author utilized a third piece in the assembly that joined the top and bottom at their ends. An improvement to simply eliminate the end plate by the upward fold of the end of the top and bottom pieces as shown in Figure 1 is the suggestion of R.M. Dickinson.

It is possible that the broad faces of the waveguide members, both top and bottom, may need some stiffening to avoid bending and "oil canning". The thin flat channels that are proposed to house the phase and amplitude references and auxiliary power lines perform this function on the slotted surface. The unslotted surfaces could be embossed to stiffen them.

The individual slotted waveguides in the array are fed from a feed waveguide shown in Figure 3 as the transverse waveguide. Transfer of energy is made through diagonal slots between the feed waveguide and radiating waveguides. The feed waveguide is attached to the array by means of pop rivets.

Construction and Evaluation

Two 8 x 8 (8 slots in 8 waveguides) arrays were constructed from 0.020 inch aluminum with the use of temporary tooling of a simple nature. The ½ inch separation between waveguides that is necessary in the forming process and which have become attractive as a region in which to mount solid state devices and through which to run cables made it necessary to adjust the dimensional specifications of the JPL design which was designed for a different fabrication method.

The slotted face plate, folded waveguide section, and the end channels were assembled to each other by spot welding. Back and front view of the finished assembly are shown in Figures 3 and 4.

In the absence of any antenna testing range a method was evolved to test the array by electrically probing each slot for amplitude and phase, as shown in Figure 5. This arrangement gave the phase and amplitude information tabulated in Table I. When readings around the outside are disregarded because of edge effects, the rms phase and amplitude percentage deviation of the remaining sections are 6.22° and 10% respectively. With the outer elements included the phase deviation is 8.89°.

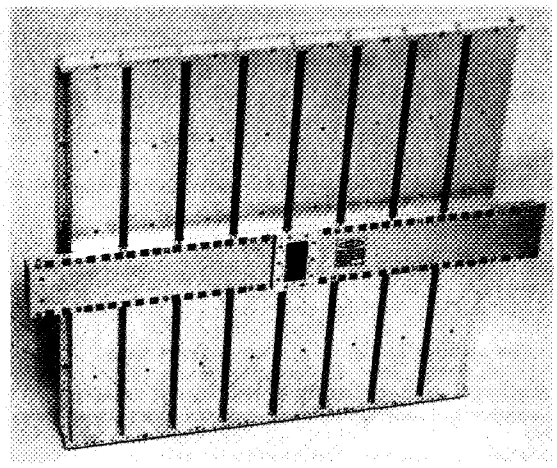

Figure 3. Back View of the 8 x 8 Slotted Waveguide Array as Constructed from 0.020 Inch Aluminum Sheet Throughout and Assembled bv Means of Soot Welding.

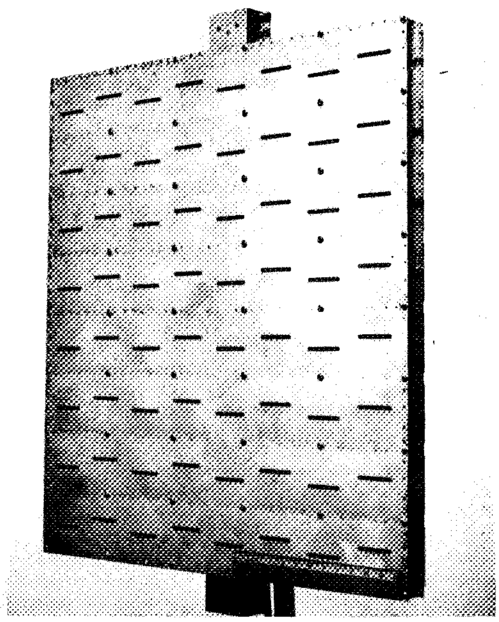

Figure 4. Front View of the 8 x 8 Slotted Waveguide Array as Constructed from 0.020 Inch Aluminum Sheet Throughout and Assembled by Means of Spot Welding.

Finally, the antenna range data taken by JPL on the array that was made for them as a portion of the contractual work effort for them is presented in Figures 6 and 7.

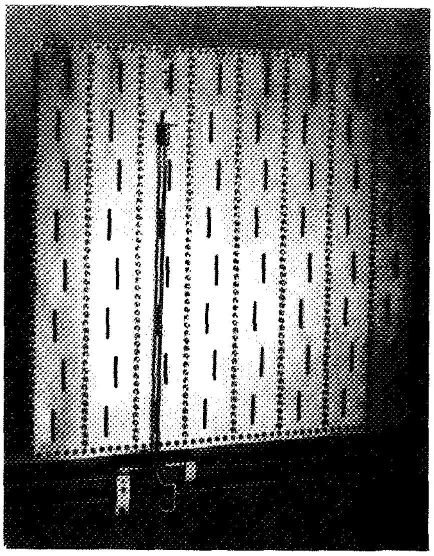

Figure 5. Probe Arrangement for Measuring Phase and Amplitude of Microwave Power Radiated at Individual Slots. The Phase and Amplitude Sensed by the Probe were Compared by Means of a Hewlett-Packard Network Analyzer with the Amplitude and Phase of the Power Input to the Single Waveguide Feed to the Slotted Waveguide Array.

TABLE I

Matrix Array of Amplitude and Phase Information on Thin Metal Slotted Array #1

Row \ Col		1	2	3	4	5	6	7	8
1	Phase	105	100	109	110	103	96	93	105
	Amp	.53	.57	.67	.70	.64	.61	.62	.62
2	Phase	104	84	80	82	91	94	79	90
	Amp	.61	.51	.59	.67	.71	.72	.59	.40
3	Phase	94	80	88	89	85	85	94	106
	Amp	.45	.58	.63	.71	.64	.58	.56	.56
4	Phase	105	79	80	73	80	89	72	94
	Amp	.61	.56	.60	.73	.73	.69	.65	.40
5	Phase	120	81	86	76	70	85	84	120
	Amp	.50	.60	.59	.72	.68	.52	.58	.50
6	Phase	96	80	74	83	92	90	79	91
	Amp	.68	.53	.57	.68	.72	.69	.60	.39
7	Phase	89	73	83	82	80	86	91	104
	Amp	.49	.60	.67	.69	.61	.60	.54	.55
8	Phase	100	86	90	93		96	88	160
	Amp	.59	.60	.53	.63		.70	.57	.45

Overall array is an 8 x 8 matrix

"Internal" array is a 6 x 6 matrix

Test data obtained by dipole probe placed in front of each radiating slot.

RMS of phase deviation of internal array is 6.22°.
RMS of phase deviation of overall array is 8.89°.
RMS of amplitude variation of internal array is 0.0628 from a mean value of 0.627.

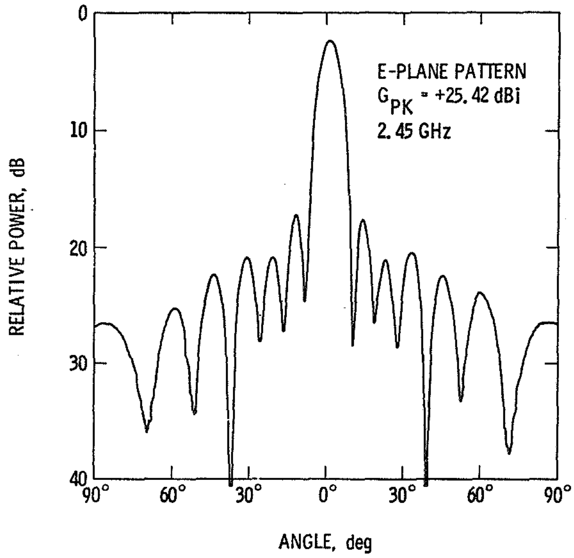

Figure 6. Antenna Pattern for 8-Slot x 8-Stick Slotted Waveguide Antenna.

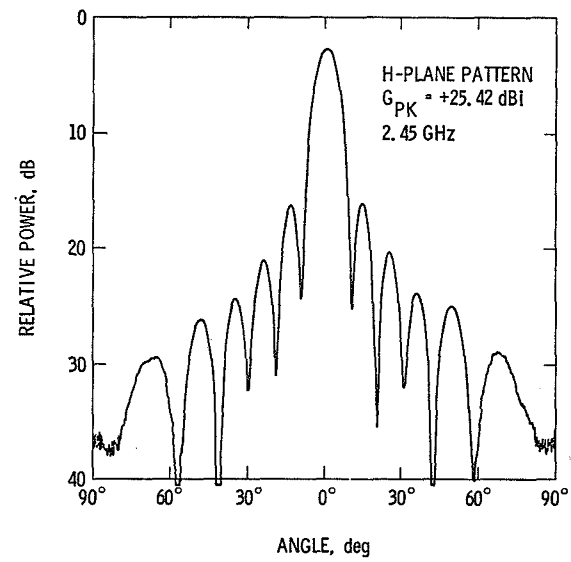

Figure 7. Antenna Pattern for 8-Slot x 8-Stick Slotted Waveguide Antenna.