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## PERFORMANCE OF A SPACE-FED LENS PHASED ARRAY

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## SUMMARY

The next generation of radar antennas will possess the properties of low sidelobes, large scan angle and wide instantaneous bandwidth. The space-fed lens configuration of Figure 1 is such an antenna. It consists of a large main lens aperture with receiving elements on one side and transmitting elements on the other. Each lens element pair is connected through either an active or passive T/R module. Illuminating this lens is a time delay steered transform feed which may be a Rotman lens, Butler matrix or Blass matrix. Each subarray port of the transform feed, is connected to a variable time delay unit and phase shifter. A circulator decouples the transmitter from the receiver. The performance of this lens together with the sensitivity of the sidelobes to excitation errors will be presented.

Each subarray port produces a sin x/x type illumination across the main aperture which is phase steered by modulo 2 T phase shifters. As a result, the radiated subarray pattern, which is sectorial in shape, scans with frequency. The array factor of the subarray ports, on the other hand, is true time delay steered and remains stationary. Its grating lobes are truncated by the subarray pattern window. This arrangement thus possess low sidelobes and reduces the number of time delayers required at the expense of bandwidth.

The number of subarray ports needed to feed a 70m linear lens with 105m focal length is investigated and the results are shown in Figure 2 where the highest sidelobe level encountered is plotted. The instantaneous bandwidth is 20 MHz at L band. Both sum and difference patterns are scanned to the maximum angle of 22.5 degrees. Taylor and Bayliss distributions are prescribed for the lens illumination with parameters  $\bar{n} = 6$ , and sidelobe level, SL = -60 dB. The achieved sidelobe level is somewhat higher because of the limited number of ports and hence sampling points on the aperture. As the number of input ports increases, the grating lobes of the array factor are spaced further and further apart until they are outside the squint range of the subarray window. Then they become severly attenuated by the low sidelobe structure of the subarray pattern. Hence one should expect to see the sidelobes dropping rapidly in the beginning and then flattening out. The minimum number of ports required is thus at the knee of the curve. In this case, eight subarray ports are needed to achieve near-in sidelobes of -40 dB. The difference channel shows poorer performance because the main beam and grating lobes are composed of two large lobes instead of one. As a result, the grating lobes are broadened. Consequently either part of the twin lobes fall within the window or the number of subarray ports has to be increased. The sum and difference patterns of this antenna are plotted in Figures 3 and 4.

The dual transform property of this antenna poses a problem in the transmit mode. Since the distribution across the feed aperture is proportional to the secondary pattern, energy is concentrated in only the few central radiating elements of the feed array. In the passive lens concept where high power is transmitted from the feed, these elements must be able to handle high peak and average power. Because of this, the active lens concept is preferable

where the transmitted power is generated in a distributed manner at the lens' modules.

The effects of excitation errors on the sidelobe level are examined by grouping them together at three interfaces. The errors from the corporate feed, time delayers and phase shifters are lumped together to form the subarray port excitation deviations at interface A. Similarly, the errors from the transform feed stacks are combined with those of the radiating elements to form the feed elements' excitation errors at interface B. Excitations of the main lens elements provide the third source of errors at interface C. Finally, failed elements on the main lens front and back faces are the fourth source of error. Deterministic expressions for the gain loss and expected antenna power pattern are obtained, given the statistics of the error sources. It can be shown, that for a planar lens, the increase in the near-in sidelobes is dependent mainly on the errors at interfaces A and B,

$$SL_{near-in} = (v_A^2 + \sigma_A^2) (h_{A1}^x h_{A1}^y + \frac{1^{-p}e}{p} h_{A2}^x h_{A2}^y) + (v_B^2 + \sigma_B^2) (h_{B1}^x h_{B1}^y + \frac{1^{e}p}{p} h_{B2}^x h_{B2}^y)$$

while the far-out sidelobe level increase is echiefly function of errors of the main lens

SL<sub>far-out</sub> =  $[(v_c^2 + \sigma_c^2) + (1-P_e)] h_c^x h_c^y / P_e$ The amplitude and phase variances at the interfaces are given by  $v_c^2$  and  $v_c^2$  respectively.  $v_c^2$  is the average fractional number of lens elements that remain operating. The  $v_c^2$  component, each of which has the same form as those of a linear lens. Only  $v_c^2$  and  $v_c^2$  are angle dependent while the rest of the coefficients produce omni-directional patterns. Using the above equations, it is found that to maintain -60 dB average far-out sidelobes for a 70m planar lens, the rms amplitude and phase error excitations for the 217,156 lens elements must be less than 1.7 dB and 12.35 respectively. Further, to achieve

lens, the rms amplitude and phase error excitations for the 217,156 lens elements, must be less than 1.7 dR and 12.35 respectively. Further, to achieve a near-in sidelobe level of -35 dB with the same variances at interface A and B, the effective amplitude and phase errors are found to be  $O_A = O_B = 3.89$  and  $V_A = V_B = 0.57$  dB. These numbers are for the case where there are 64 subarray ports and 400 feed radiating elements. The expected power pattern has been evaluated with several values of P and plotted in Figure 4. The far-out sidelobe level is seen not to be particularly sensitive to element failures. With 10% failure, the far-out sidelobes have only deteriorated to -56.3 dB from -60 dB.

Of equal importance is a knowledge of the peak sidelobe statistics. This can be obtained by dividing the sidelobe level increase with the normalised error-free sidelobe to obtain the normalised error power  $\sigma_{\rm F}$ . Then the probability that the normalised sidelobe level is less than a desired level in the presence of the error power is given by the modified Rayleigh distribution and may be obtained from Figure 5. Applying this procedure to the planar lens whose far-out error power is at -60 dB, it is found that the probability is 90% with no sidelobes exceeding -53.6 dB and -56.1 dB in regions where the no-error sidelobes are -60 dB and -75 dB respectively. In the near-in region where the no-error peak sidelobe is -46 dB with the error power at -35 dB, the probability is 90% that the sidelobes will not exceed -31 dB.

## **ACKNOWLEDGEMENT**

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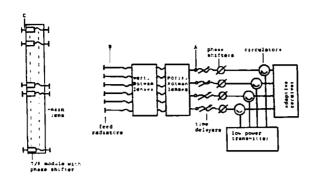


Figure 1 Active Lens Concept

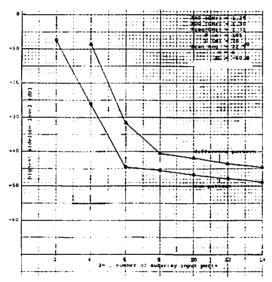


Figure 2 Sidelobe Level Versus Number of Subarray Ports for Lens with F/L = 1.50

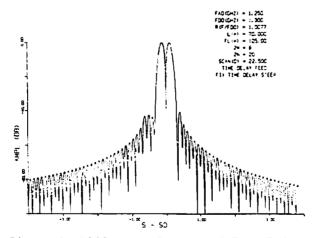
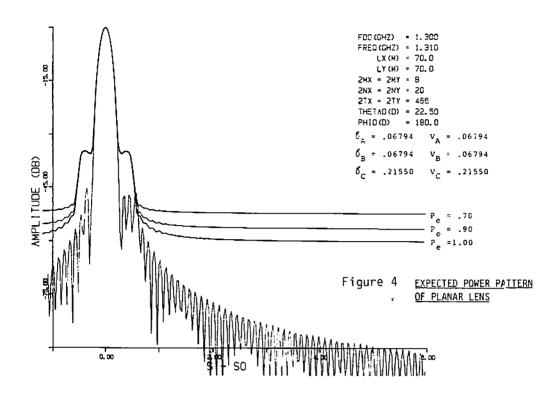


Figure 3 Difference Pattern of Feed-Through Lens



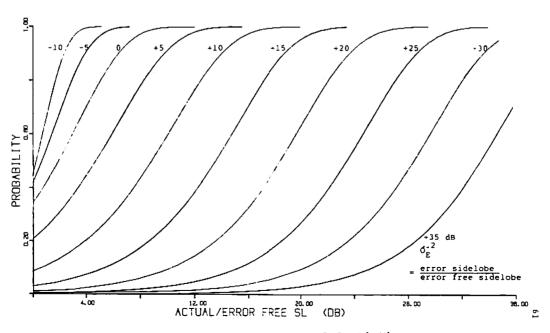


Figure 5 Peak Sidelobe Level Statistics