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MODIFICATION OF THE AN/TRC-97A ANTENNA SYSTEM, (U)
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MODIFICATION OF THE AN/TRC-97A ANTENNA SYSTEM.

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This report presents the results of an analysis of the AN/TRC-97A critical troporadio antenna to determine what possible sidelobe reduction can be attained. Theoretical results are presented on the effect of feed and sub reflector blockage on the radiation patterns. In addition, radiation patterns are included on a modified feed support structure of the existing system which results in improved sidelobes in the azimuth plane.
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1. INTRODUCTION

In response to a request by HADC/DCCT, RAOC/EAA undertook the task of investigating the feasibility of improving the sidelobe structure of the AN/TRC-97A Troposscatter Antennas. The approach taken in this study was to evaluate options that would, in varying degrees, utilize the present reflector and so achieve a system improvement at low cost to the government. The options, ranked in order of increasing complexity and cost are to simply alter the feed horn illumination on the main lens, to reduce or redistribute feed blockage if possible, to use a Cassegrain configuration with a small subreflector for low blockage, and finally to procure an offset reflector antenna with a highly tapered illumination. This report includes theoretical studies in Appendices A and B that address these options, and in addition it presents experimental data of a potentially low cost option that lowers the sidelobes in the azimuth plane at the expense of elevation plane sidelobes.

2. GENERAL DISCUSSIONS

Existing AN/TRC-97A Troposscatter Antennas were designed more than ten years ago during an era of modest ECM/ARM capability. Consequently design

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emphasis on extremely low sidelobe levels, a must in today's ECM environment, was not required. A sketch of the original parabola and feed horn assembly is shown in Figure 1. The sidelobe level in the immediate proximity to the main beam is due to the following:

1. Aperture illumination of the reflector by the feed,
2. Distortion and/or manufacturing tolerances of the reflector,
3. Aperture blockage due to the feed structure.

The wide angle sidelobes are due primarily to spillover energy radiated by the feed and not intercepted by the reflector. No attempt was made in this study to address this problem because of the dominance of the near sidelobes.

The approach taken in this study was to conduct a theoretical investigation coupled with an experimental modification program.

1. Theoretical investigation: to determine
   a) Effect of feed blockage,
   b) Analysis of sidelobes predicted by a Cassegrain system,
   c) Best sidelobe structure possible with other alternatives,

2. Experimental investigations:
   a) Redesigning the feed horn,
   b) Rerouting existing waveguide runs to reduce the blockage sidelobes in the azimuth plane.

Figure 1. Original Feedhorn and Waveguide Assembly
3. THEORETICAL RESULTS

The theoretical investigations were conducted by Ronald L. Fante, and the results presented are in the letter report of 4 January 1980, "A Study of the Effect of Feed Blockage on the AN/TCR-97A Antenna" (see Appendix A) and the letter report of 20 February 1980, "Analysis of the Effect of Subreflector Blockage on the Radiation Pattern of a Cassegrain Modification to the AN/TCR-97A Antenna" (see Appendix B). The results suggest: (1) that changing dish illumination will not significantly reduce the sidelobe levels as the computed data indicate that the primary source of the sidelobes is strut and waveguide blockage; and (2) that because of subreflector blockage it does not appear possible to design a Cassegrain (monopod) modification to yield sidelobes less than -30 dB; but that degree of improvement is likely possible using the present reflector tolerances and with careful engineering of the subreflector size and taper. Recent results with offset fed reflector antennas indicate that far better sidelobe structures can be obtained by these configurations at the possible expense of some polarization deterioration. This is an issue that must be considered further should the decision be taken to seek very low sidelobe patterns.

Figures 2 and 3 show the plots of the calculations made by Fante for both polarizations of: (1) The Cassegrain-Monopod case; and (2) the best possible case attainable with the existing system having optimum dish illumination with no blockage. The two cases are compared with the patterns of the original antenna, obtained from RADC/DCCT. Figure 2 is a comparison of the vertical polarization patterns while Figure 3 compares the horizontal polarization patterns.

Note that to the main beam there is little advantage to using the Cassegrain system, as the sidelobe level remains high; however, beyond ±10° a distinct advantage is obtained as the sidelobes are reduced considerably.
Figure 2. Comparison of the Original AN/TRC-65A Patterns With Ronald L. Fante's Calculations (Vertical polarization)

Figure 3. Comparison of the Original AN/TRC-65A Patterns With Ronald L. Fante's Calculations (Horizontal polarization)
1. EXPERIMENTAL INVESTIGATION OF A COMPROMISE ALTERNATIVE

It is shown in the Appendices that changing the dish illumination of the existing AN IRC-97 feed would not reduce the near-in sidelobes because of the permanent blockage condition. However, since the most critical aspect of the system is the azimuth plane sidelobe structure, a possible compromise solution is to route the existing waveguide runs and change the strut assembly to improve the sidelobes in the azimuth plane without changing the average sidelobe level in the other planes. An experimental investigation was initiated to evaluate two alternatives.

The modification consisted of removing the struts from the horizontal plane, and connecting them at a 45° angle from the horizontal plane of courses 1 and 2. In addition, the waveguide runs were rerouted from the vertical plane to the horizontal plane. One feed now originates at 0° and the other at 180° on the plane of the dish. This modification resulted in changing the original feed annular to a feed periphery 45° from the original feed structure. Thus, azimuth patterns now have non-circular deformation and comparable to the original azimuth patterns taken with vertical polarization. The vertical patterns are also opposite in polarization from the originals.

![Figure 4. Modified Feedhorn and Waveguide Assembly](image)

Principal plane patterns were taken for both modifications of the modified feed structure and compared with the patterns sent to us by RCA of the original feed.

As noted earlier, the polarization for equivalent main patterns between the original and modified patterns differed by 90° due to the switch of the feed annulus and the 45° struts over the horns. The patterns taken with the revised set were:

- Figure 4. Modified Feedhorn and Waveguide Assembly
were associated with the original process.

During this modification, the utilities were included in the main assembly as the wavelength was used in analyzing the data and for various monitoring. With the existing utilities, it was possible to obtain significant data at a lower cost and a more accurate output. Thus, data processing was significantly improved for the entire system. In addition, we ensured that the system would be self-paced and automatic.

Figures 1 and 2 show patterns that relate to specific polarizations, respectively. The solid line patterns were the DORI patterns while the dashed line patterns were the NOCI patterns and the \textit{LC} line patterns were used in the \textit{LCN} setup.

Figures 3 and 4 are patterns that were used to identify the shape and orientation of the \textit{LCN} system. The patterns are shown for various conditions, and the resulting measurements were used to analyze the data.

In addition, the system was designed to operate at various conditions, which were specified in the original design. These conditions were identified and tested to ensure the reliability of the system. The design was then adjusted as necessary to ensure the best possible performance.
Figure 5. Comparison of the Original AN TRC 65A Patterns With the Modest Feed Structure Patterns [Vertical polarization (4.7 GHz)]

Figure 6. Comparison of the Original AN TRC 65A Patterns With the Modest Feed Structure Patterns [Horizontal polarization (4.7 GHz)]
Figure 7. Comparison of the Original AN/TRC-97A Patterns With the Modified Feed Structure Patterns [Vertical polarization (4.5 GHz)]

Figure 8. Comparison of the Original AN/TRC-97A Patterns With the Modified Feed Structure Patterns [Horizontal polarization (4.5 GHz)]
Figure 9. Comparison of the Original AN/TRC-97A Patterns With the Modified Feed Structure Patterns [Vertical polarization (4.9 GHz)]

Figure 10. Comparison of the Original AN/TRC-97A Patterns With the Modified Feed Structure Patterns [Horizontal polarization (4.9 GHz)]
5. CONCLUSIONS

It is apparent from Ronald L. Fante's calculations and these measurements that no simple solution exists that will result in reduction in the sidelobe level of the AN/TRC-97A antenna beyond -30 dB. To achieve an appreciable improvement over the existing waveguide-feed combination an offset fed system should be considered. (See for instance RADC Report TR-77-313 entitled "EUCM Antenna Development" by RCA and RADC Report TR-77-2204, "Design of Parabolic Cylinder Reflector System with Low Sidelobes", R.L. Fante.)

Another alternative, that would yield lower sidelobes than the existing feed structure in the azimuth plane, but cause some degradation in the elevation plane, would be to relocate the feed structure as in Figure 4 of the experimental work. This results in a sidelobe decrease of approximately 10 dB in the main beam area of the azimuth plane patterns (± 10°) and a sidelobe improvement of about 7 dB beyond ± 10°.
Appendix A

A Study of the Effect of Feed Blockage
On The AN/TRC-97A Antenna

We have studied the effect of feed blockage on the performance of the AN/TRC-97A antenna. A drawing of the front view of this antenna is shown in Figure A1.

In the absence of any blockage the field radiated by this antenna can be written as

\[ E_0(r) = \frac{2T}{\lambda} \int_0^\pi \int_0^{\pi/2} r \, \text{d}r \, \text{d}\theta \, \exp \left\{ -ikr \sin \theta \cos (\phi - \phi_0) \right\} \]

\[ = \frac{2T}{\lambda} R_0^2 \int_0^{\pi/2} \text{d}(\text{sin}(1/2) \phi) \int_0^{\pi/2} \text{d}(\text{sin}(1/2) \phi) J_0(kR_0 \sin \phi^{1/2}) \]  

(1A)

where \( R_0 = 4 \) is the radius of the parabolic reflector, \( \lambda \) is the wavelength, and \( J_0(\cdot) \) is a Bessel function. Also \( k = \frac{2\pi}{\lambda} \), \( \lambda = 2.34 \) inch.

In the realistic system there is blockage due to the struts, the waveguide, and the feed assembly. By using data in the Radar Cross Section Handbook\(^1\) we have calculated the effective blockage width \( A = 2.51 \) in. of the waveguide and the struts. These are summarized in Table A1. The blockage due to the feed assembly has been approximated by a circular blockage region of radius \( r_b \). This equivalent model is shown in Figure A2.

Figure A1. Front view of AN-THR-5A Antenna.

Table A1. Input flare blockage widths of the waveguides and struts in AN-THR-5A A.

<table>
<thead>
<tr>
<th></th>
<th>Horizontal Polarization</th>
<th>Vertical Polarization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front flare of</td>
<td>80 in.</td>
<td>80 in.</td>
</tr>
<tr>
<td>Front flare of</td>
<td>60 in.</td>
<td>60 in.</td>
</tr>
</tbody>
</table>

Using the aforementioned blockage model, we obtain for the field in the V Plane:

\[
\begin{align*}
&\text{Horizontal Polarization:} \\
&\quad \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} R_1(x, y, z) \, dx \, dy \, dz \\
&\quad \text{Vertical Polarization:} \\
&\quad \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} R_2(x, y, z) \, dx \, dy \, dz
\end{align*}
\]

\[\text{where } R_1 \text{ and } R_2 \text{ are the field components.}\]
If \( f(r) \) is relatively constant over \( 0 \leq r \leq R_s \) we can approximate \( f(r) \) in the second term in Eq. (A2). Upon performing the integrals we then get

\[
\phi(r) = \frac{2\pi R_s^3}{k R_s^3} \int_0^1 \frac{1}{x^2} \sin(x) \, dx \\
= \frac{4\pi R_s}{k R_s^3} \left[ 1 - \frac{\sin(\frac{W_s}{R_s})}{\frac{W_s}{R_s}} \right] \sin^2 \left( \frac{W_s}{R_s} \sin^2 \phi \right)
\]

where the values for \( W_s \) and \( W_d \) are those in Table A1 appropriate for the polarization chosen. Also, \( I_{1,0} \) is the Bessel function of order one and 

\[ I_{1,0} \left( \frac{W_s}{R_s} \sin^2 \phi \right) \]

\[ I_{1,0} \left( \frac{W_d}{R_s} \sin^2 \phi \right) \]

\[ I_{1,0} \left( \frac{W_s}{R_s} \sin^2 \phi \right) \]

\[ I_{1,0} \left( \frac{W_d}{R_s} \sin^2 \phi \right) \]

\[ I_{1,0} \left( \frac{W_s}{R_s} \sin^2 \phi \right) \]

Figure A2. Equivalent Model for Blockage by Feed,
Waveguides, and Struts
In writing Eq. (A4) we have ignored the effect of strut blockage in the \( \phi - \theta' \) plane, because it has the same beamwidth as the unblocked pattern.

Equations (A3) and (A4) have been evaluated numerically and the results are shown in Figures A3 through A6. Also shown on Figures A3 through A6 is measured data. Note that the theory predicts roughly the same blockage sidelobe levels as are measured.

In Figure A7 we show the calculated pattern [using Eq. (A3)] for the case when all blockage is removed, but the illumination on the dish has the same taper \( f(r) \) as the present AN/TRC-97A. In Figure A7 we also show the radiation pattern which would be obtained if the only blockage were a 5-in. diameter circular region at the center of the aperture. This is typical of the type of blockage which would be present if the illumination were produced using a dielectric-supported subreflector.

The sidelobes shown in Figure A7, for the case of the 5-in. diameter circular blockage, are not improved significantly by reducing the edge taper on the reflector. This is evident from Figures A7a and A7b, where we compare the radiation pattern of the reflector (with 5-in. and 10-in. diameter circular blockage) for the case of -12 dB edge illumination with -26 dB edge illumination.

We have also calculated the residual sidelobe levels which are produced by tolerance errors in the construction of the AN/TRC-97A reflector. The specified rms surface tolerance is 1.16 in., but the lateral correlation length is unknown. The average sidelobe level at \( \theta \) due to tolerance errors is

\[
S_l = \frac{1}{2} k b^2 \frac{2 \sin^2 \theta}{R^2} \exp \left( - \frac{k b^2 \sin^2 \theta}{4} \right) \cos^4 \left( \frac{\theta}{2} \right)
\]

where \( b \) is the rms surface error and \( a \) is the surface-error correlation length. The worst-case sidelobes occur for a \( 2b \sin \theta \). We then get

\[
S_l \text{WORST} = \frac{5.80 b^2 \cos^4 \left( \frac{\theta}{2} \right)}{R^2 \sin^2 \theta}
\]

In Figure 8 we show the worst-case error sidelobes, along with those for surface correlation lengths of 1/4 in., 1 in., 4 in., and 8 inches. Even for worst-case correlations the error sidelobes of the AN/TRC-97A reflector will be below -30 dB for \( \theta > 15^\circ \).


If the diameter of the feed were 10 in. instead of 5 in., the blockage sidelobe would be as shown in Figure A3b.
Figure A3. Pattern for Horizontal Polarization in the Horizontal Plane

Figure A4. Pattern for Horizontal Polarization in the Vertical Plane
Figure A5. Pattern for Vertical Polarization in the Horizontal Plane

Figure A6. Pattern for Vertical Polarization in the Vertical Plane
Figure A7. Radiation Pattern of the AN/TRC-97A Reflector
(12 dB Edge Illumination)

Figure A7a. Radiation Pattern of the AN/TRC-97A Reflector With Blockage
by 5-in. Diameter Circular Feed for Two Different Edge Illuminations. The
-12 -dB represents the present TRC-97A.
Figure A8b. Radiation Pattern of the AN/TRC-97A Reflector With Blockage by 10-in. Diameter Circular Feed for Two Different Edge Illuminations.

Figure A9. Average Sidelobe Levels Due to Reflector Tolerance Errors for Different Correlation Lengths. (a)
Conclusions

Consideration was given to the possibility of reducing the correlation error of the presented data by introducing a new illumination field. However, this was not done because it was felt that the correlation error of the presented data would not be affected significantly by changing the illumination field. This conclusion is based on the fact that the correlation error is dependent on the illumination field, assuming that the illumination field is not changed drastically.

The correlation error of the presented data is known to be due to the presence of correlation error in the illumination field. This correlation error is due to the fact that the illumination field is not uniform over the entire illumination field.

Because the correlation error of the presented data is known to be due to the presence of correlation error in the illumination field, it is possible to calculate the correlation error of the presented data by using the correlation error of the illumination field.

Because the correlation error of the presented data is known to be due to the presence of correlation error in the illumination field, it is possible to calculate the correlation error of the presented data by using the correlation error of the illumination field.

Recommendations

The present AN-TRC-9A antenna configuration will have near-sin sidelobe levels of order of 50 dB for high T/R changing the dish illumination will not affect that conclusion because the sidelobes are due to blockage by the central lobe.

The near-sin sidelobes could be reduced to roughly 40 dB by removing the blockage except a centrally located feed or by using 20 g 20 g or more than the amount of power on the feed illumination.

Sidelobes of order of 50 dB or lower can possibly be achieved by a proper offset beam. However, because of mechanical tolerance errors the maximum 50 dB the sidelobes would be less than 50 dB for - 180°, 180° and - 180°.

The feed could be a helix and a supported collector for more uniform coverage over the

...
Appendix B

Analysis of the Effect of Subreflector Blockage on the Radiation Pattern of a Cassegrain Modification to the AN/TRC-97A Antenna

III. ANALYSIS

In this appendix, we will calculate the sidelobe levels for the AN/TRC-97A antenna when it is fed in an optimally designed Cassegrain configuration. The minimum blockage design corresponds to the case when the shadow cast upon the main reflector by the feed is exactly equal to the shadow cast by the hyperboloidal subreflector. Upon referring to Figure B.1 we see that this condition is expressed via the equations

\[ \tan \theta = \frac{D_B}{2B} \]  
(3.11)

\[ \frac{D_B}{B} = \frac{d_{m}}{F_r} \]  
(3.12)

where \( D_B \) is the diameter of the hyperboloidal subreflector, \( \theta \) is the angle subtended at the feed by the subreflector edge, \( d_{m} \) is the feedhorn diameter, \( F_r \) is the distance between the two feet of the hyperboloid (the field horn is at one of the

---

foci and the other focus coincides with the focus of the main paraboloidal reflector, \( F \) is the focal length of the paraboloidal main reflector and \( S = F_c - (D_F/2) \cot \alpha \).

\[ F_c = \frac{D_F}{2} \]

Figure III. Geometry of the Modified AN/TRC-97A Antenna

If we desire that the edge taper on the hyperboloid (and consequently on the paraboloid) is approximately -20 dB relative to the illumination at its center, it can be shown \(^8\) that for an optimally-designed conical feed horn

\[ \Phi_{-20} = \frac{1.74 \lambda}{d_{in}} \quad \text{radians} \]

where $\lambda$ is the signal wavelength. Equation (133) is valid in the magnetic plane of the horn, and is not quite correct in the electric plane.

If we combine Eqs. (H1) and (H2), along with the definition of $S$ we obtain

$$\tan \phi = \frac{2}{2A - \frac{1}{2}} - \frac{1}{2} \cot \phi.$$  \(\text{(134)}\)

Finally, using Eq. (135) to express $d_{\text{m}}$ in terms of $\phi$ we get

$$d_{\text{m}} = \left( \frac{3.48 \lambda}{F} \left( \frac{\tan \phi}{\phi} \right)^{1/2} \right).$$  \(\text{(135)}\)

Equation (135) expresses the minimum possible blockage diameter in terms of the angle $\phi$ subtended at the focus by the main reflector edge, and the angle $\phi$ subtended at the feed by the subreflector (for the case when the subreflector edge illumination is <20 dB). We also note that once $\phi$ and $\phi$ are chosen the subreflector eccentricity, $e$, follows immediately via

$$e = \frac{\sin \frac{1}{2} (\phi + \phi)}{\sin \frac{1}{2} (\phi - \phi)}.$$  \(\text{(136)}\)

Also, once $\phi$ is specified the diameter, $d_{\text{m}}$, of the feed horn is given by Eq. (H3).

The AN/TRC-97A has a focal length of approximately 3.2 ft, a wavelength, $\lambda$, of 2.51 in, and $\phi = 60^\circ$. Using these values we obtain the results shown in Table H1.

<table>
<thead>
<tr>
<th>$\phi$ (degrees)</th>
<th>$d_{\text{m}}$ (ft)</th>
<th>$d_{\text{m}}$ (ft)</th>
<th>$e$</th>
<th>$\lambda$ (ft)</th>
<th>$2 \frac{d_{\text{m}}^2}{\lambda}$ (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>1.43</td>
<td>1.04</td>
<td>1.78</td>
<td>1.81</td>
<td>10.35</td>
</tr>
<tr>
<td>30</td>
<td>1.41</td>
<td>0.65</td>
<td>2.5</td>
<td>1.11</td>
<td>4.62</td>
</tr>
<tr>
<td>40</td>
<td>1.40</td>
<td>0.521</td>
<td>3.79</td>
<td>0.752</td>
<td>2.6</td>
</tr>
<tr>
<td>50</td>
<td>1.41</td>
<td>0.417</td>
<td>6.38</td>
<td>0.54</td>
<td>1.66</td>
</tr>
<tr>
<td>60</td>
<td>1.44</td>
<td>0.348</td>
<td>25.3</td>
<td>0.40</td>
<td>1.16</td>
</tr>
</tbody>
</table>

From Table H1, we see that the minimum possible subreflector diameter, $d_{\text{m}}$, is approximately 1.4 feet. This result is relatively insensitive to the subreflector eccentricity, $e$. From the last two columns of Table H1 we also note that the
distance, $\delta$, from the feed to the subreflector is generally less than $(2 d_m^2/\lambda)$, so that the subreflector is not quite in the Fraunhofer zone of the feed. It is most nearly in the Fraunhofer zone when the feed is close (high eccentricity to the subreflector, as is evident from Table B1).

At this point we shall calculate the effect of the subreflector blockage on the radiation pattern of the main reflector, for the case when the main reflector has a -20 dB edge taper. This result is shown in Figure B2. We observe from this figure that the feed blockage (caused by the hyperboloidal subreflector) produces near-in sidelobes which are greater than -30 dB, although the far-out (angles greater than 9.7°) sidelobes are below -40 dB.

![Figure B2. AN/TRC-97A Radiation Pattern With Minimum Blockage Cassgrain Feed and -20 dB Edge Taper](image)

One might ask if we do any better by "backing-off" to a -14 dB edge taper, rather than a -20 dB taper. In this case Eq. (B3) is replaced by $\phi_{-13} \leq 1.4 \lambda/d_m$ and we then find that the minimum possible subreflector diameter is $D_B = 1.19$ feet. However, when we calculate the radiation pattern of the AN/TRC-97A reflector with this blockage and a -14 dB edge illumination we again get near-in sidelobes greater than -30 dB (in fact the first sidelobe is roughly -22 dB), as is evident from Figure B3.
B2. CONCLUSION AND RECOMMENDATION

Because of subreflector blockage it does not appear possible to design a Cassegrain-subreflector modification to the AN/TRC-97A which will yield a system radiation pattern with all sidelobes less than -30 dB. If this performance is desired an offset fed system seems to be the simplest alternative.

B2.1 Design of the Conical Feed Horn

If we should choose to build the Cassegrain system we will need a test-horn design, as shown below in Figure B4.
If we desire only the $\text{TE}_{11}$ mode in the waveguide feeding the horn we must choose "$a$" such that

$$2.61a < \lambda < 3.41a,$$

because the cutoff wavelength $\lambda_c$ of the $\text{TE}_{11}$ is $3.41a$ and that of the next mode ($\text{TM}_{01}$) is $2.61a$. If we choose $3a - \lambda$ we have

$$2a = \frac{2\lambda}{3} - \frac{(2.51)^2}{3} = 1.67 \text{ inch}.$$  

The dimensions $l$ and $f$ are determined from the equations given by King (1950)

$$\frac{l}{\lambda} = 0.3 \left( \frac{d_m}{\lambda} \right)$$

$$\frac{f}{\lambda} = 0.3 \left[ 1 + \left( \frac{d_m}{\lambda} \right)^2 \right]$$

and the horn angle $\psi$ is determined via

$$\cos \psi = \left( \frac{d_m}{\lambda} \right)^2$$

$$\left[ 1 + \left( \frac{d_m}{\lambda} \right)^2 \right]$$

$$\rho = 0.3 \lambda \left[ 1 + \left( \frac{d_m}{\lambda} \right)^2 \right] - \frac{a}{\sin \psi}.$$
As an example, consider the design for the case when \( \psi = 6.88 \) in Table B1. In this case \( (d_{12}/\lambda) = 1.90 \) so that

\[
\left( \frac{l}{r} \right) = 1.1^\circ,
\]

\[
\left( \frac{\phi}{\lambda} \right) = 1.4^\circ,
\]

\[
\cos \psi = 0.798,
\]

\[
\psi = 37^\circ.
\]

and

\[
\left( \frac{\psi}{\lambda} \right) = 0.936.
\]

B2.2 Example of Hyperboloidal Subreflector Design

The hyperboloid is designed as shown in Figure B5.

![Figure B5](image-url)
In Figure 15, \( a = (F_c/2c) \) and \( b = (F_c/2) + a \) and

\[
X_B = \left[ \left( \frac{F_c}{2c} \right)^2 + \frac{D_B^2}{4c^2} \right]^{1/2}.
\]

If we choose to design the system in Table B1 for which \( c = 6.85 \), we have

\( F_c = 0.946 \text{ ft}, \) \( D_B = 1.41 \text{ ft}, \) \( a = 0.0687 \text{ ft}, \) \( b = 0.541 \text{ ft}, \) and \( X_B = 0.124 \text{ feet} \).
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