PASSIVE REPEATER ENGINEERING

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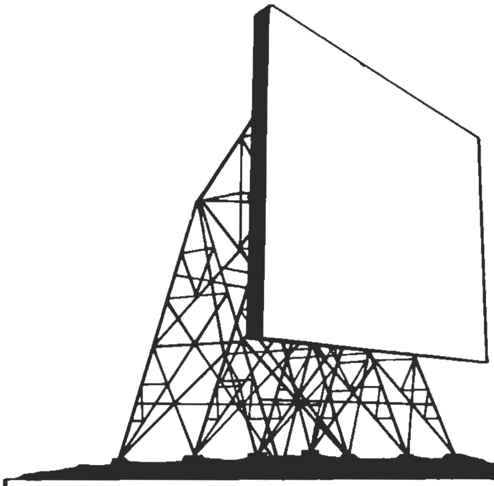
CATALOG 161A



Passive Repeater Engineering

Manual No. 161A

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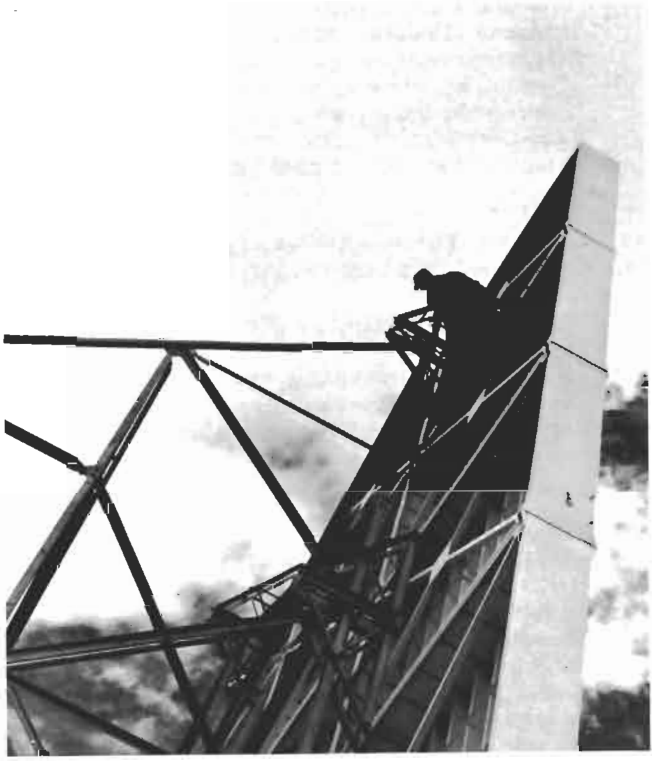
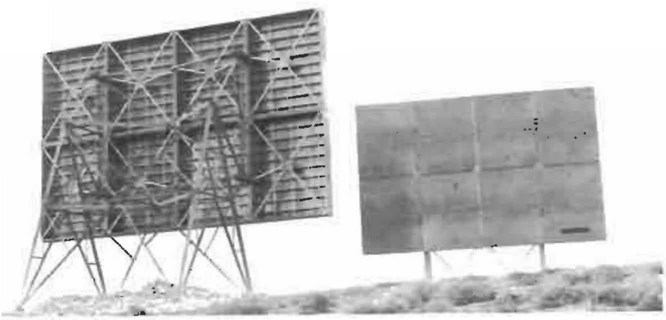
CHAPTER I

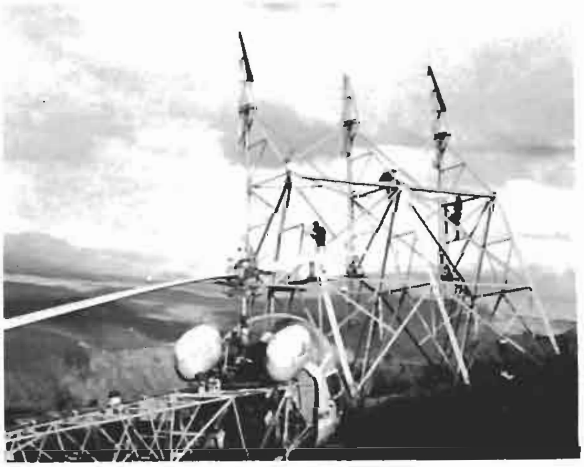
PASSIVE REPEATER APPLICATIONS

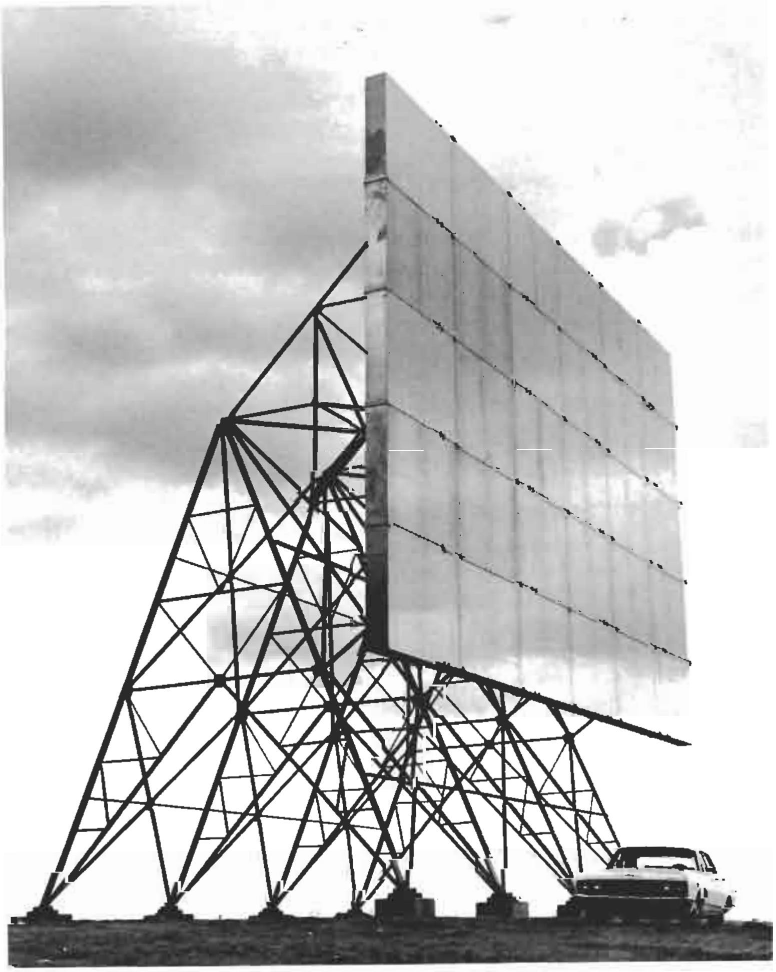
Microflect Company has been engineering, manufacturing and installing passive repeaters since 1956 and has thousands of units operating successfully throughout the world. Passive repeaters are used to change the direction of a microwave path to overcome obstructions, reduce the number of active repeaters required, and provide for more convenient locations for them near existing roads and power lines. The passives require no access or power lines and virtually no maintenance. Total costs are therefore greatly reduced compared to similar systems not using passive repeaters.

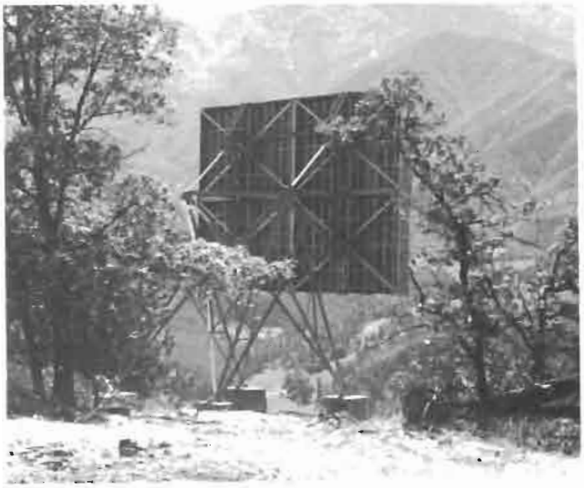
Examples in this chapter illustrate applications that are installed and operating. An effort has been made to show a variety of path configurations with the technical data available.

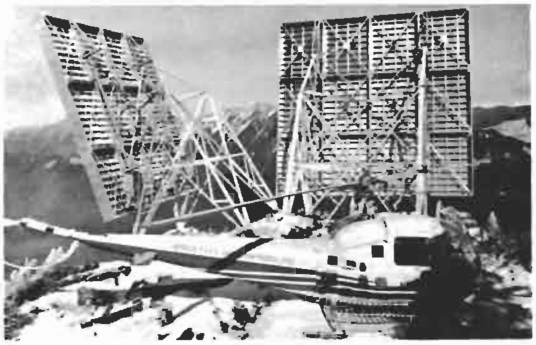








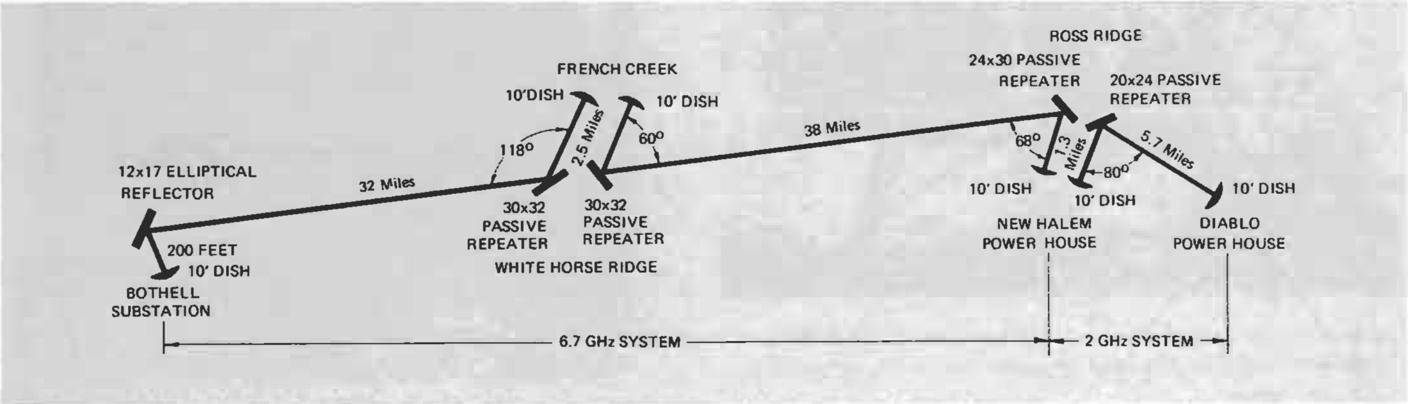




Seattle City Light engineers and Microflect engineers analyzed the problem of transmitting telemetry and voice communications from Seattle City Light's Diablo Powerhouse and Newhalem Powerhouse to existing monitoring facilities at Bothell Substation near Seattle.

Snow depths of 15' to 20' in this area of the Pacific Northwest are not unusual, even at relatively low elevations of 4,000' above mean sea level. Accordingly, it was decided to place the one active repeater station required for the system at French Creek near Darrington, Washington. Passive repeaters provide the necessary elevation for clear paths to the respective points of communication.

Application of two additional passive repeaters on Ross Ridge turned the Newhalem Powerhouse into an active repeater/terminal. It would have been a spur terminal if an active repeater had been placed at Ross Ridge. This conversion of spur terminals to terminal repeaters is an increasingly common practice in the backbone of mountainous microwave systems.



We have added this reference list to help you quickly locate a specific example of a class of passive repeater application that may be of interest to you.

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Longest Path (68.5 miles)	17
Mid and near Mid-Path Applications (38 miles) (22.5 miles) (48.6 miles)	11,13,18
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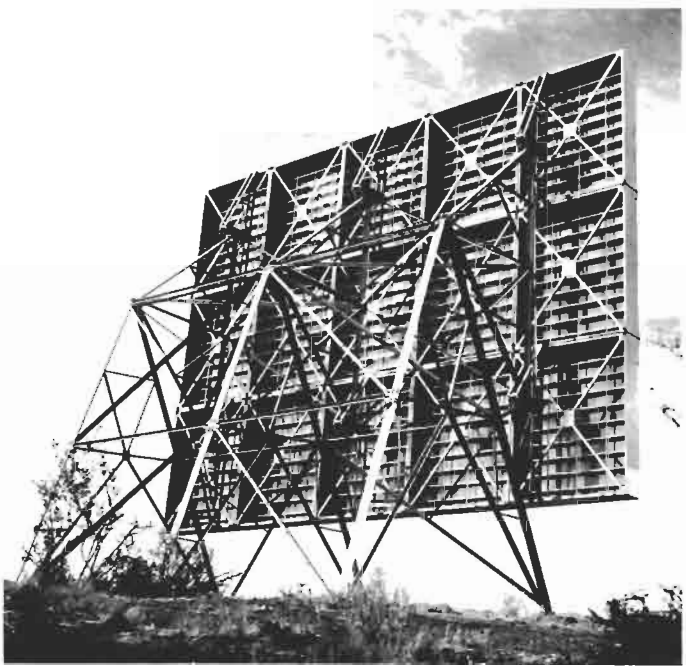
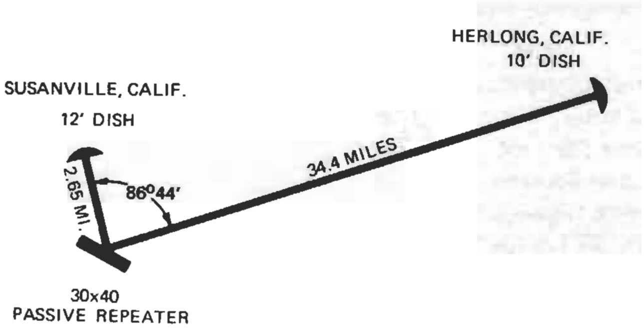


A 30x40 passive repeater of this type was installed for Citizens Utilities Company of California in the system shown below.



6 GHz SYSTEM
600 VOICE CHANNEL CALCULATIONS

GAINS

Transmitter	+31.0 dBm
Antenna 12'	44.6 dB
Antenna 10'	43.0 dB
	+118.6 dBm

LOSSES

7.7 db	2.65 Miles(Near field)
145.2 dB	34.4 Miles
4.5 dB	Waveguide, Equip., & Misc.

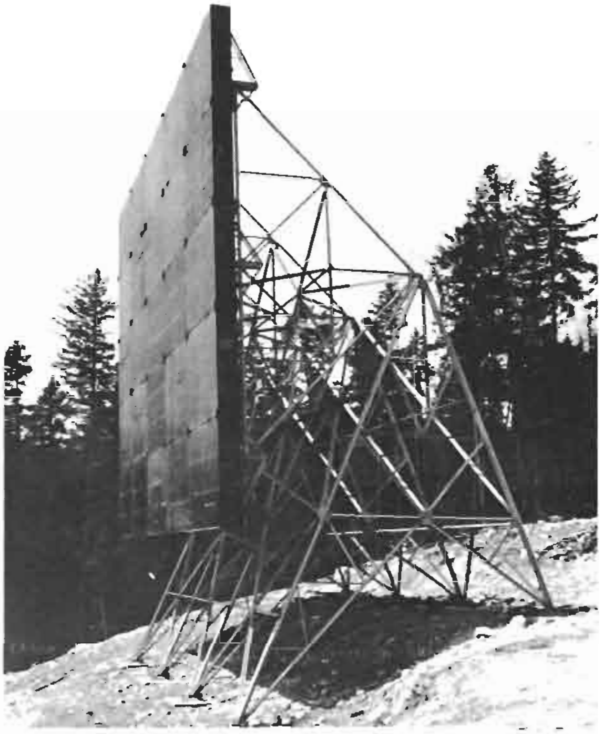
−157.4 dB
+118.6 dB

−38.8 dBm Received Signal Level

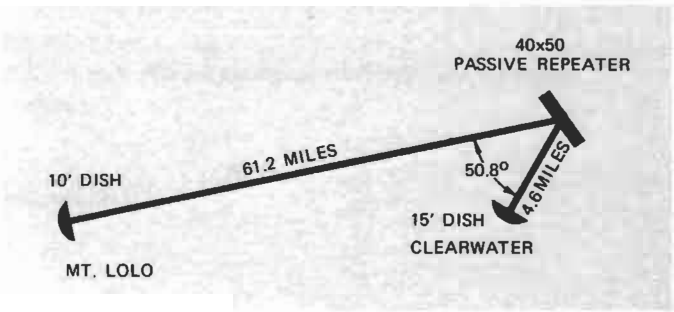
−81.2 dBm FM Improvement Threshold
− 38.8 dBm Received Signal

42.4 dB Fade Margin

Noise, Worst Slot, 23 dBrnCO.



The footing levels of this 40x50 passive repeater, installed by British Columbia Telephone, were designed to conform to the sloping site.



7.4 GHz SYSTEM
240 VOICE CHANNEL CALCULATIONS

GAINS

Transmitter	+27.0 dBm
Antenna 10'	44.5 dB
Antenna 15'	48.0 dB
	+119.5 dBm

LOSSES

149.9 dB	61.2 Miles
6.4 dB	Waveguide, Equip., & Misc.
5.6 dB	40 x 50 Reflector

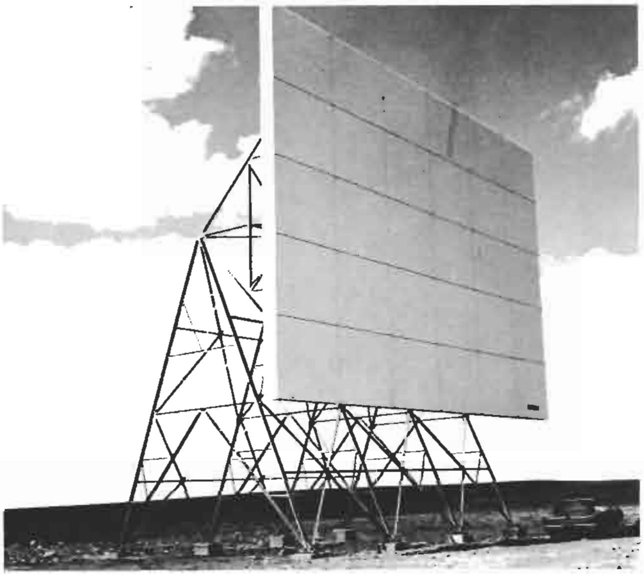
−161.9 dB
+119.5 dBm

− 42.4 dBm Calculated Received Signal Level
− 41.0 dBm Measured Received Signal Level

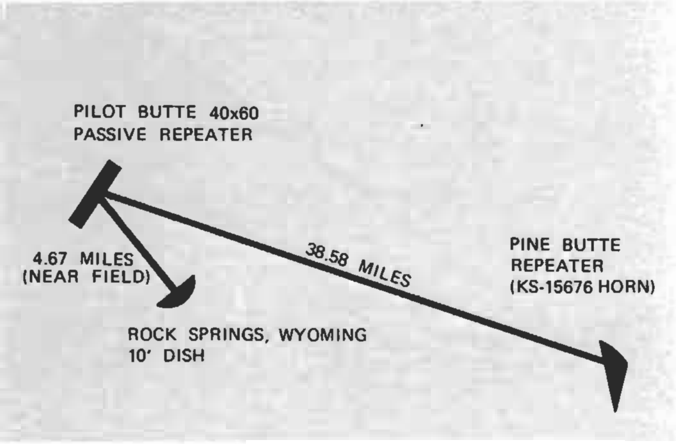
− 81.0 dBm FM Improvement Threshold
− 41.0 dBm Received Signal

40.0 dB Fade Margin

Noise, worst slot, 25.0 dBrnCO



A 40 x 60 passive repeater installed for Mountain Bell, Wyoming, near Rock Springs, Wyoming, in a 6 GHz microwave system.



6 GHz SYSTEM
600 VOICE CHANNEL CALCULATIONS

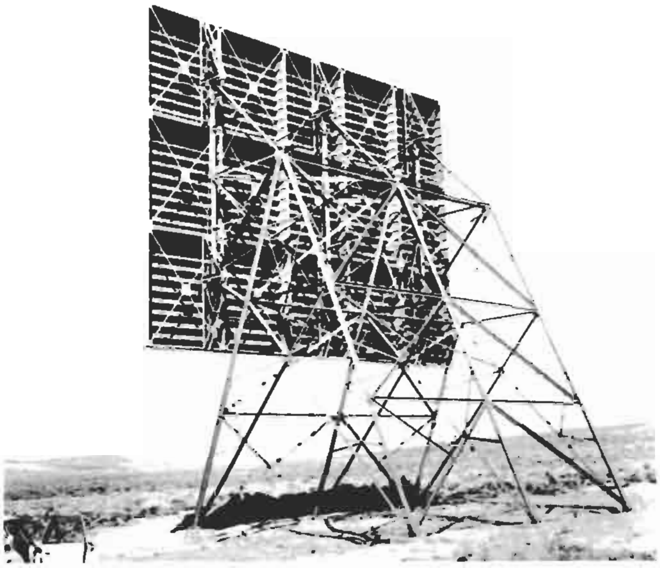
GAINS

Transmitter	+ 30.0 dBm
Antenna 10'	43.0 db
Antenna (10' Horn)	43.0 dB
	+116.0 dB

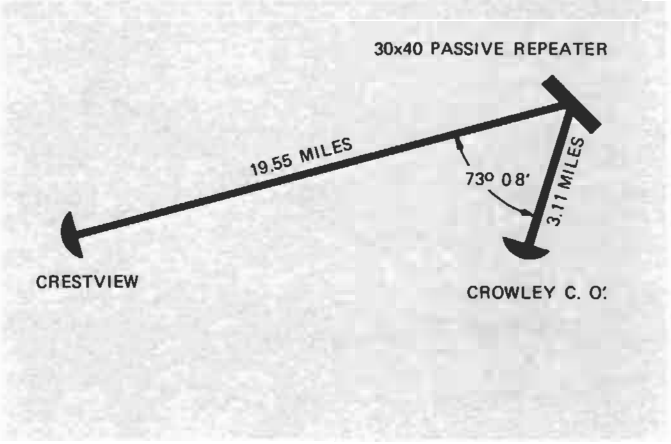
LOSSES

4.6 dB	4.67 Miles (Near field)
144.7 dB	38.58 Miles
5.4 dB	Waveguide
−154.7 dB	
+116.0 dB	
− 38.7 dBm	Received Signal Level

−78.0 dBm	FM Improvement Threshold
−38.7 dBm	Received Signal
39.3 dB	Fade Margin



Continental Telephone Company of California uses this 30x40 passive repeater in the system shown below.



2 GHz SYSTEM
72 VOICE CHANNEL CALCULATIONS

GAINS

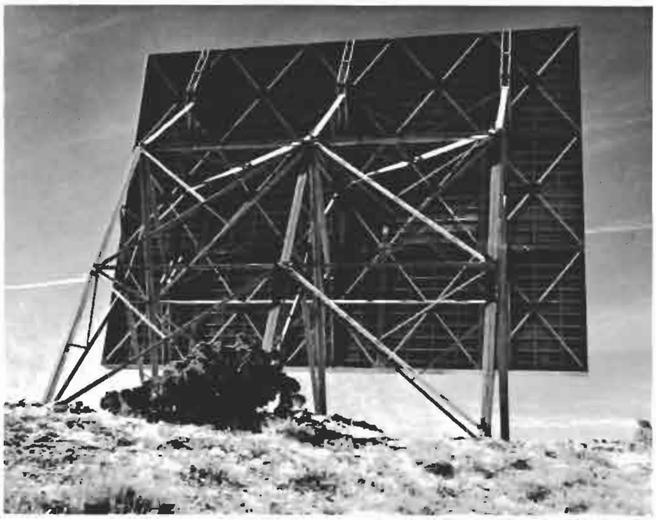
Transmitter	+ 33.0 dBm
30' x 40' Passive	94.9 dB
10' Dish	34.0 dB
10' Dish	34.0 dB
	+195.9 dBm

LOSSES

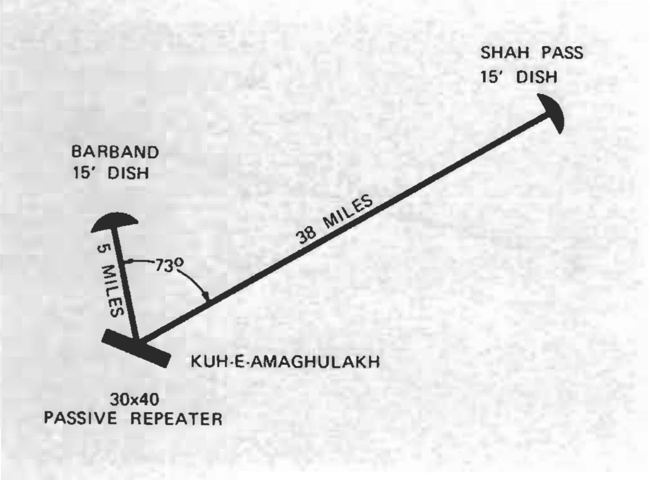
113.2 dB	3.11 Miles
129.2 dB	19.55 Miles
8.9 dB	Equip. & Trans. Lines
-251.3 dB	
+195.9 dBm	
− 55.4 dBm	Received Signal Level

− 92.0 dBm	FM Improvement Threshold
− 55.4 dBm	Received Signal
36.6 dB	Fade Margin

Noise, worst slot 23.7 dBrnCO.



A typical 30 x 40 passive repeater installation similar to the one installed in the path shown below for the Iranian Posts Telephone and Telegraph earth satellite microwave back haul link.



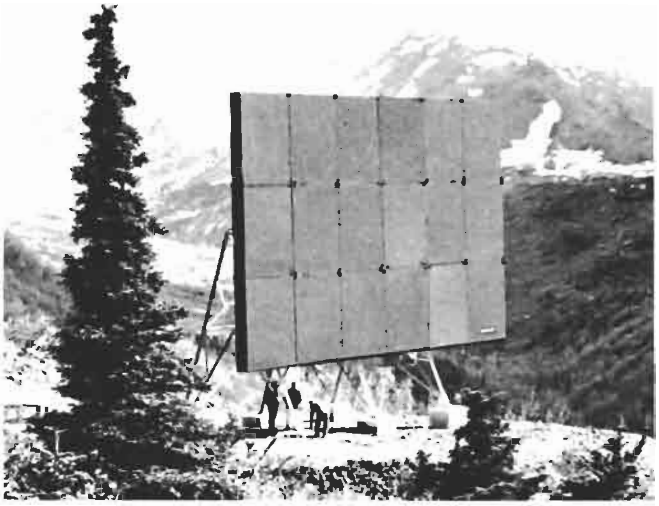
6.7 GHz SYSTEM
1200 VOICE CHANNEL CALCULATIONS

GAINS

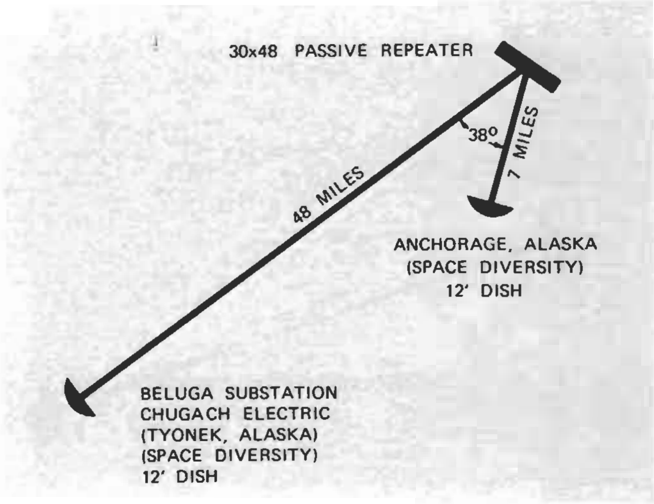
Transmitter	+40.0 dBm
Antenna 15′	47.0 dB
Antenna 15′	47.0 dB
30x40 Passive Repeater	115.0 dB
	+249.0 dB

LOSSES

145.3 dB	38.0 Miles
129.9 dB	5.0 Miles
2.1 dB	Waveguide and Coax
−277.3 dB	
+249.0 dB	
– 28.3 dBm	Received Signal Level
−77.0 dBm	FM Improvement Threshold
−28.3 dBm	Received Signal
48.7 dB	Fade Margin



A 30 x 48 passive repeater installed near Anchorage, Alaska for Chugach Electric.



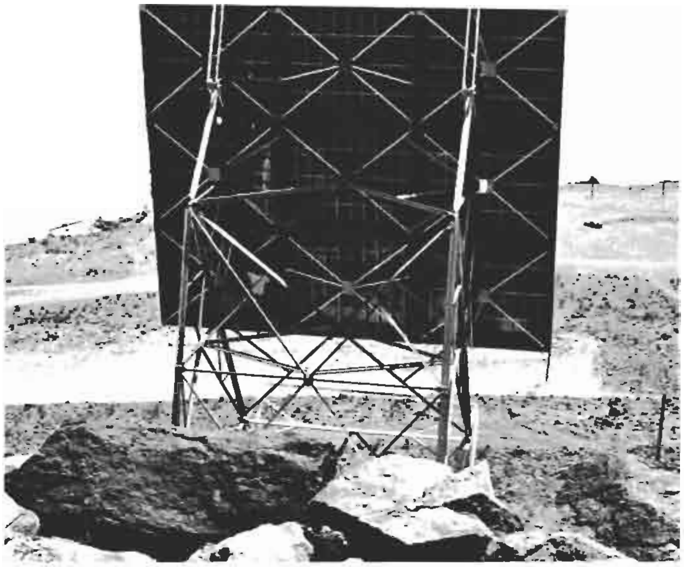
6.7 GHz SYSTEM
300 VOICE CHANNEL CALCULATIONS

GAINS

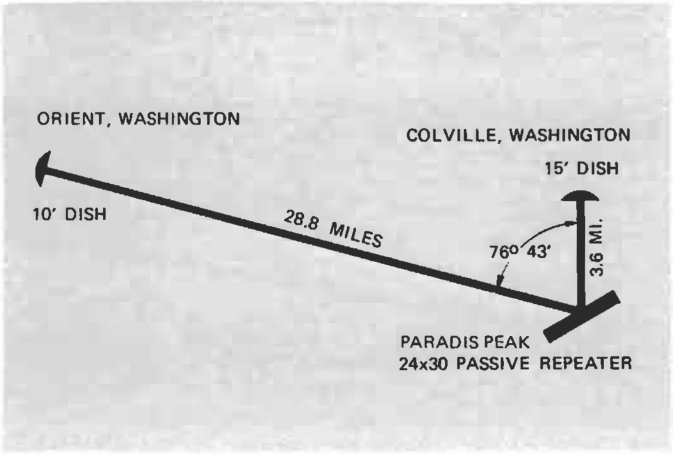
Transmitter	+24.5 dBm
Antenna 12′	46.0 dB
Antenna 12′	46.0 dB
30x48 Passive Repeater	118.0 dB
	+ 234.5 dB

LOSSES

126.0 dB	7 Miles
146.7 db	48 Miles
6.0 dB	Waveguide and Coax
− 278.7 dB	
+ 234.5 dB	
− 44.2 dBm	Received Signal Level
− 86.0 dBm	FM Improvement Threshold
− 44.2 dBm	Received Signal
41.8 dB	Fade Margin



A 24x30 passive repeater similar to the one above is used at Paradis Peak by Pacific Northwest Bell



2 GHz SYSTEM
72 VOICE CHANNEL CALCULATIONS

GAINS

Transmitter	+33.0 dBm
Antenna 10'	33.0 dB
Antenna 15'	36.8 dB
24 x 30 Passive Repeater	90.0 dB
	+192.8 dBm

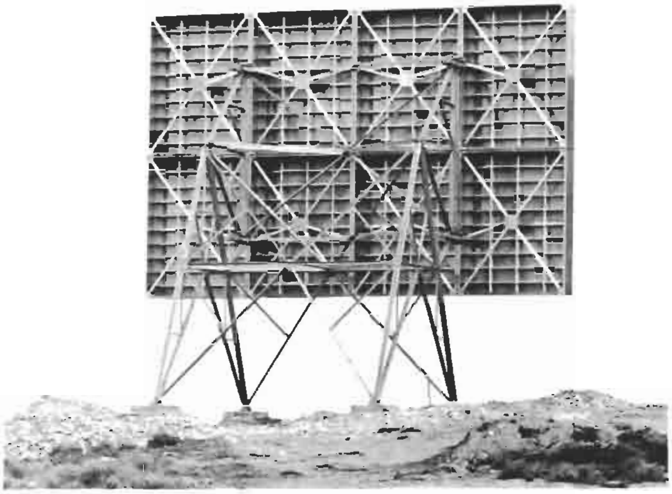
LOSSES

113.7	3.6 Miles
131.8	28.8 Miles
1.9	Hardware

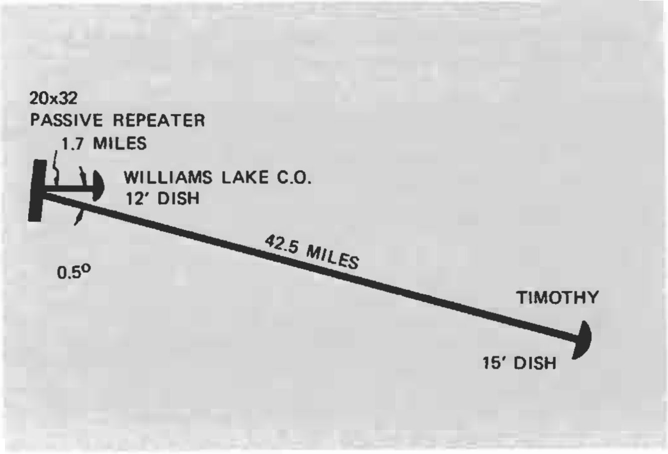
- 247.4
+192.8
- 54.6 dBm Received Signal Level

- 91.4 dBm FM Improvement Threshold
- 54.6 dBm Received Signal
36.8 dB Fade Margin

Noise, worst slot, 41.5 dBrnCO at - 91.4 dBm Received Signal
Noise, worst slot, 22.5 dBrnCO at - 54.6 dBm Received Signal



A 20x32 Passive repeater of this type is used at Williams Lake by British Columbia Telephone.



7.4 GHz SYSTEM
600 VOICE CHANNEL CALCULATIONS

GAINS

Transmitter	+30.0 dBm
Antenna 15'	48.2 dB
Antenna 12'	46.3 dB
	+ 124.5 dBm

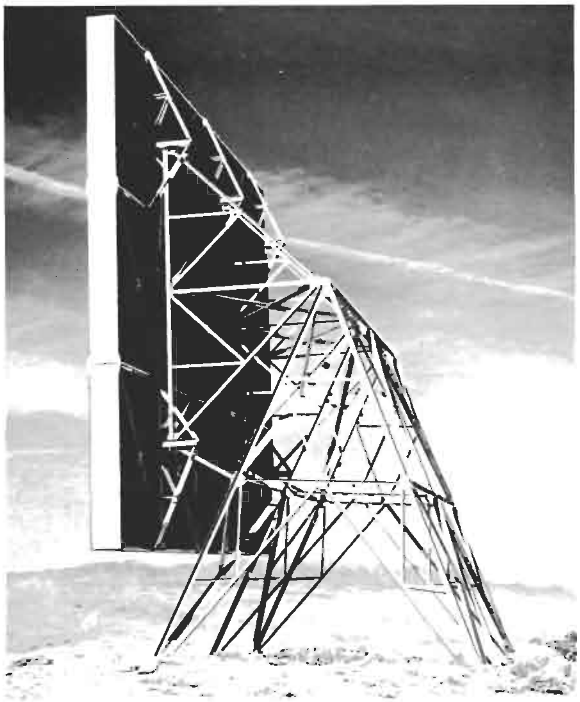
LOSSES

146.6 dB	42.5 Miles
5.5 dB	1.7 Miles (Near field)
9.3 dB	Waveguide, Connectors, & Misc.

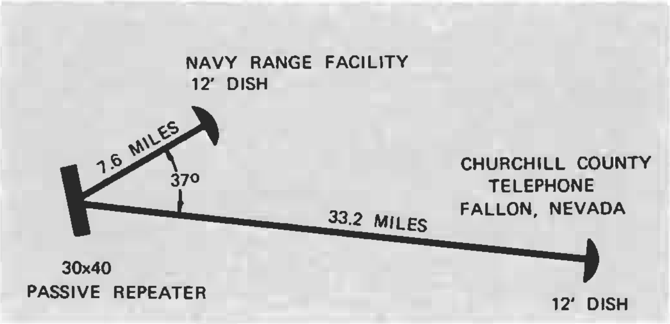
-161.4 dB
+124.5 dBm
- 36.9 dBm Calculated Received Signal Level
- 36.9 dBm Measured Received Signal Level

-78.0 dBm FM Improvement Threshold
- 36.9 dBm Received Signal Level
41.1 dB Fade Margin

Noise, worst slot, 19.5 dBrn CO



A 30 x 40 passive repeater installed near Fallon, Nevada in an 11 GHz path for Churchill County Telephone Company.



11 GHz SYSTEM
600 VOICE CHANNEL CALCULATIONS

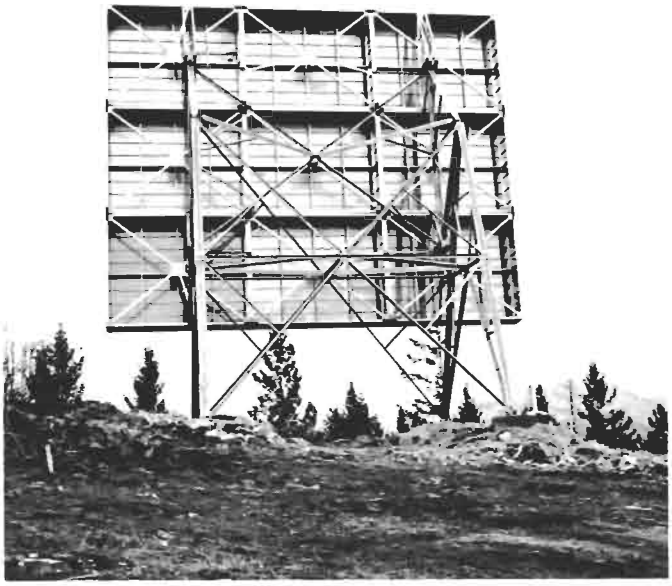
GAINS

Transmitter	+27.0 dBm
Antenna 12'	48.8 dB
Antenna 12'	48.8 dB
30x40 Passive Repeater	124.3 dB
	+248.9 dB

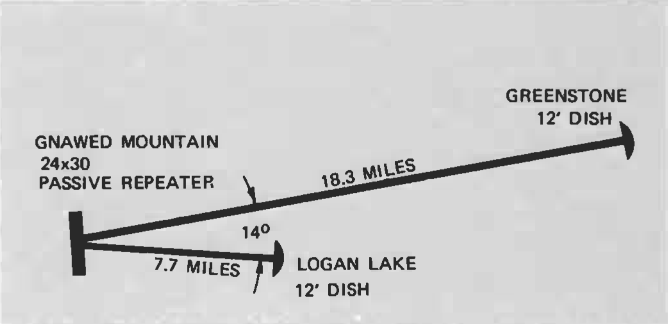
LOSSES

135.2 dB	7.6 Miles
148.0 dB	33.2 Miles
9.6 dB	Waveguide and Coax
− 292.8 dB	
+ 248.9 dB	
− 43.9 dBm	Received Signal Level

−72.0 dBm	FM Improvement Threshold
− 43.9 dBm	Received Signal
28.1 dB	Fade Margin



British Columbia Telephone uses a 24 x 30 passive repeater in the system below. Passives are available with either eight or fifteen foot ground clearance (Distance from the bottom of the face panels to the ground). The model above has an eight foot ground clearance. Higher ground clearances up to 150 feet are available for special applications.



7.4 GHz SYSTEM
300 VOICE CHANNEL CALCULATIONS

GAINS

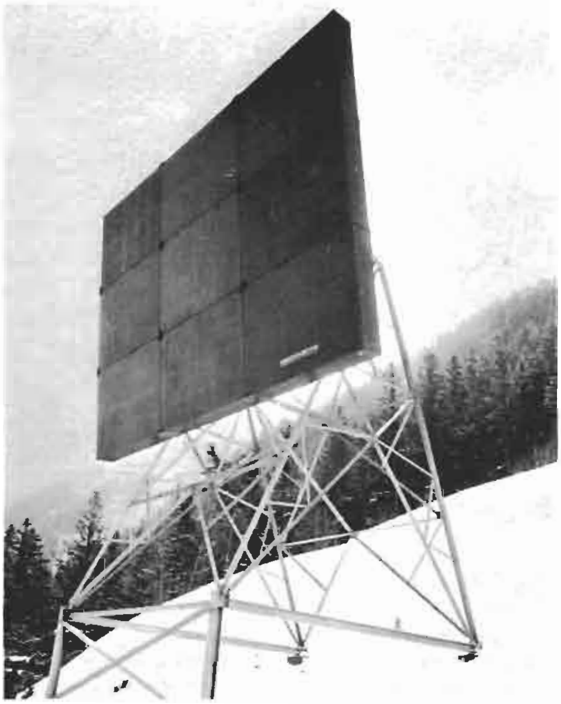
Transmitter	+30.0 dBm
Antenna 12'	46.4 dB
Antenna 12'	46.3 dB
24' x 30' Passive Repeater	114.5 dB
	+237.2 dBm

LOSSES

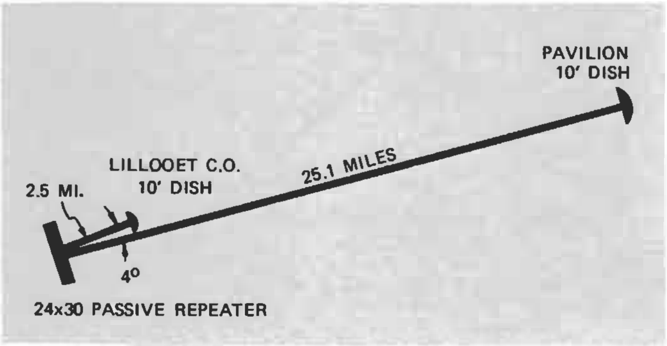
139.3 dB	18.3 Miles
131.7 dB	7.7 Miles
9.0 dB	Waveguide, Connectors, and Misc.
−280.0 dB	
+237.2 dBm	
− 42.8 dBm	Calculated Received Signal Level
− 41.0 dBm	Measured Received Signal Level

− 81.0 dBm	FM Improvement Threshold
− 41.0 dBm	Received Signal Level
40.0 dB	Fade Margin

Noise, worst slot, 24 dBrnCO



A 24 x 30 passive installed for British Columbia Telephone. Note how an interface structure was used to support the passive on a sloping site.



7.4 GHz SYSTEM
240 VOICE CHANNEL CALCULATIONS

GAINS

Transmitter	+27.5 dBm
Antenna 10'	44.7 dB
Antenna 10'	44.7 dB
	+116.9 dBm

LOSSES

143.0 dB	25.1 Miles
7.6 dB	2.5 Miles (Near field)
9.3 dB	Waveguide, Connectors and Misc.

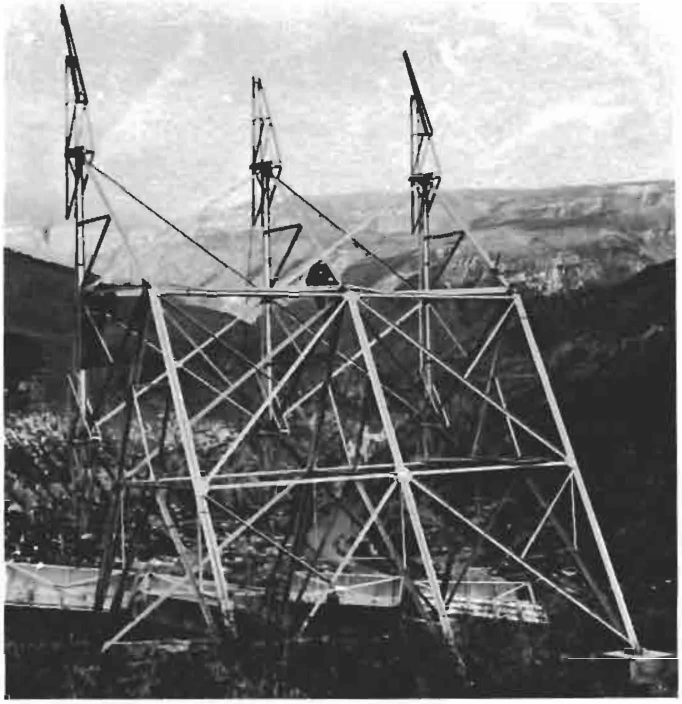
−159.9 dB
+116.9 dBm

−43.0 dBm Calculated Received Signal Level
−43.0 dBm Measured Received Signal Level

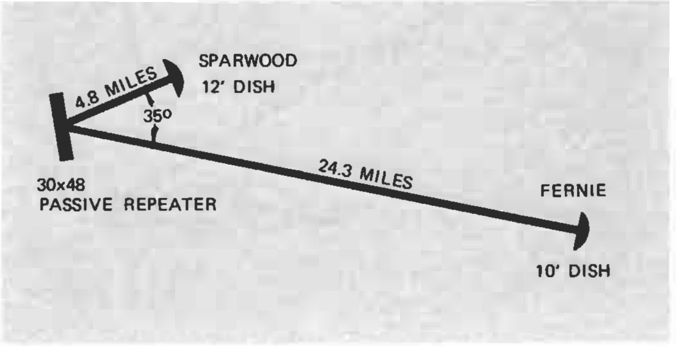
−81.0 dBm FM Improvement Threshold
−43.0 dBm Received Signal Level

38.0 dB Fade Margin

Noise, worst slot, 25 dBrnCO



A 30 x 48 passive under construction. British Columbia Telephone uses this type of passive in the application shown below.



7.4 GHz SYSTEM
300 VOICE CHANNEL CALCULATIONS

GAINS

Transmitter	+30.0 dBm
Antenna 10'	44.8 dB
Antenna 12'	46.2 dB
	+121.0 dBm

LOSSES

141.7 dB	24.3 Miles
8.0 dB	4.8 Miles (Near field)
10.6 dB	Waveguide, Connectors and Misc.

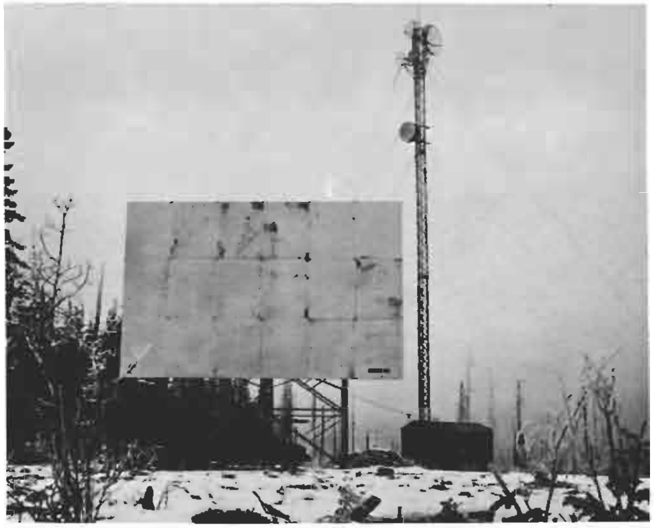
−160.3 dB
+121.0 dBm

−39.3 dBm Calculated Received Signal Level
−39.0 dBm Measured Received Signal Level

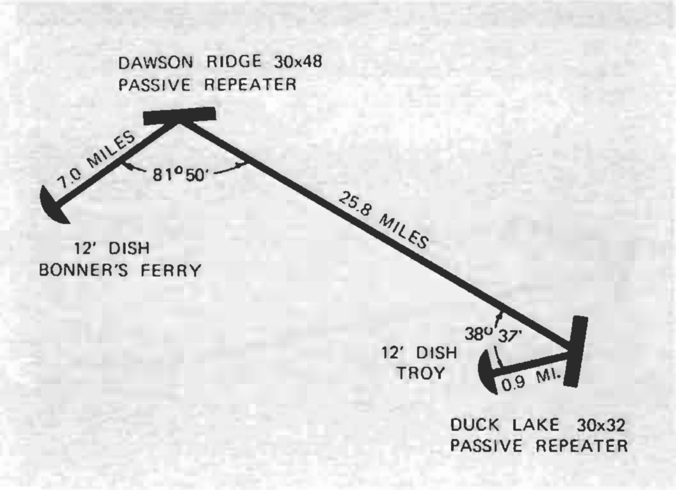
−81.0 dBm FM Improvement Threshold
−39.0 dBm Received Signal Level

42.0 dB Fade Margin

Noise, worst slot, 19.8 dBrnCO



Here, a 30 x 48 passive repeater is installed to phase out the repeater in the background. This passive repeater is installed near Bonner's Ferry, Idaho.



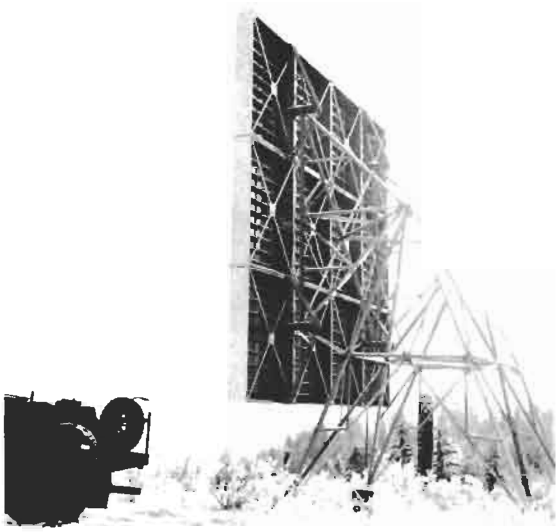
11 GHz SYSTEM 600 VOICE CHANNEL CALCULATIONS

GAINS

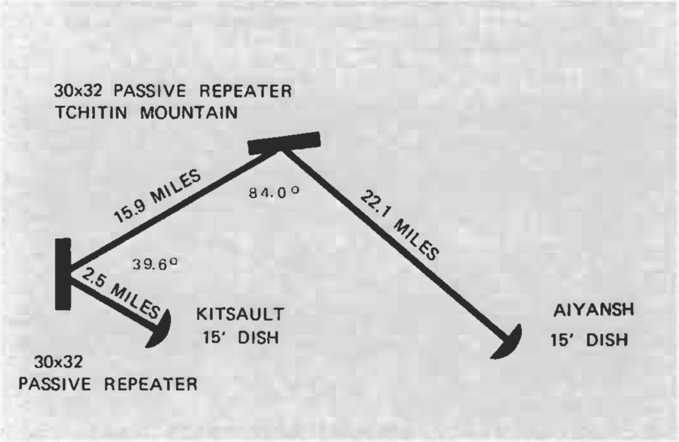
Transmitter	+27.5 dBm
Antenna 12'	49.0 dB
Antenna 12'	49.0 dB
Passive Repeater 30x32 (near field 0.9 mi.)	3.8 dB
	+ 129.3 dB

LOSSES

9.9 dB	7.0 Miles (Near Field)
145.7 dB	25.8 Miles
7.2 dB	Waveguide and Connectors
− 162.8 dB	
+ 129.3 dB	
− 33.5 dBm	Received Signal Level
− 75.0 dBm	FM Improvement Threshold
− 33.5 dBm	Received Signal
41.5 dB	Fade Margin



Two 30 x 32 passive repeaters like this one were installed in a microwave path by British Columbia Telephone. Roads and power were non-existent in the area and winter in this British Columbia Province would make an access road impassable. (Note that the product of the path lengths is 878).



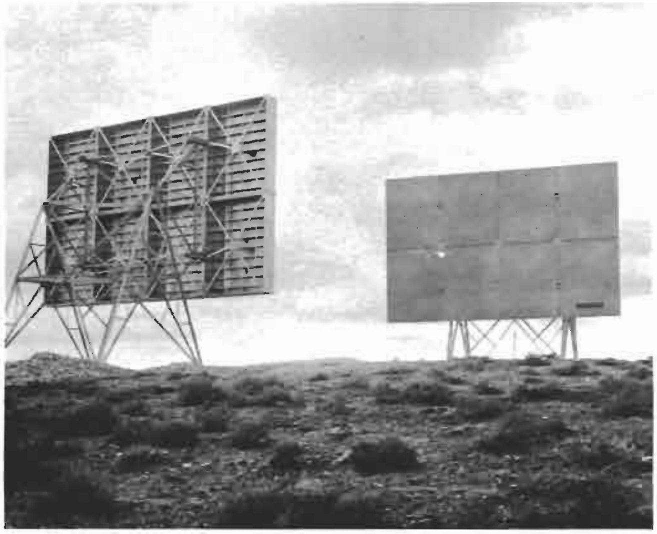
7.5 GHz SYSTEM 300 VOICE CHANNEL CALCULATIONS

GAINS

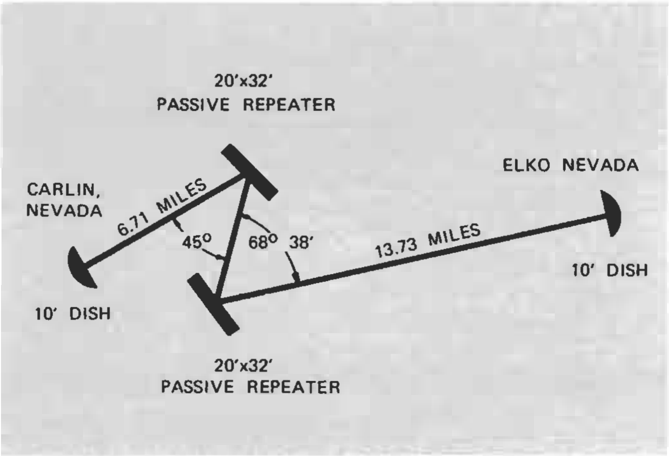
Transmitter	+ 27.0 dBm
Antenna 15'	48.9 dB
Antenna 15'	48.9 dB
Passive Repeater (Tchitin Mountain)	116.0 dB
	+240.8 dB

LOSSES

142.0 dB	22.1 Miles
138.5 dB	15.9 Miles
6.0 dB	2.5 Mile Path (Near Field)
2.5 dB	Waveguide And Connectors
−289.0 dB	
+240.8 dB	
− 48.2 dBm	Received Signal Level
− 81.0 dBm	FM Improvement Threshold
− 48.2 dBm	Received Signal
32.8 dB	Fade Margin



Double 20 x 32 passive repeater installed in a 2 GHz link between Elko and Carlin, Nevada.



2 GHz SYSTEM
72 VOICE CHANNEL CALCULATIONS

GAINS

Transmitter	+33.0 dBm
Antenna 10'	34.5 dB
Antenna 10'	34.5 dB
Passive repeater	88.0 dB
	+190.0 dB

LOSSES

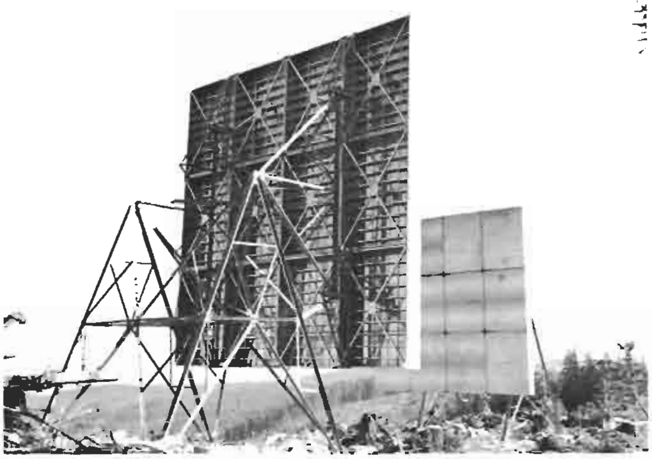
118.8 dB	6.71 Miles
126.0 dB	13.73 Miles
2.2 dB	Coax and Connectors
1.0 dB	Double Passive

– 248.0 dB
+ 190.0 dB

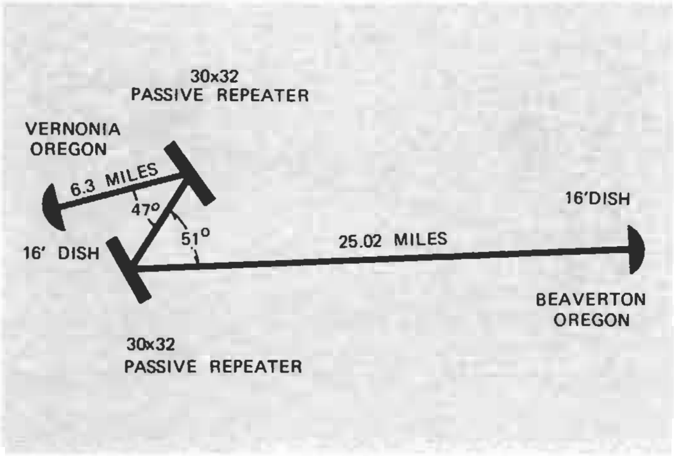
– 58.0 dBm Received Signal Level

– 93.0 dBm FM Improvement Threshold
– 58.0 dBm Received Signal

35.0 dB Fade Margin



Double 30 x 32 passive repeater installed in a 6 GHz microwave link for General Telephone of the Northwest between Beaverton and Vernonia, Oregon.



6 GHz SYSTEM
600 VOICE CHANNEL CALCULATIONS

GAINS

Transmitter	+27.5 dBm
Antenna 16'	47.0 dB
Antenna 16'	47.0 dB
30x32 Passive Repeater	112.8 dB
	+234.3 dB

LOSSES

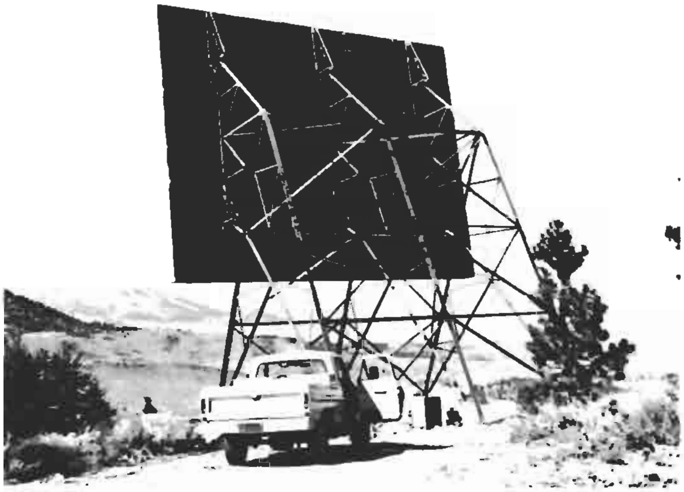
128.5 dB	6.3 Miles
140.4 db	25.02 Miles
4.2 dB	Waveguide and Coax
0.7 dB	Double Passive

– 273.8 dB
+ 234.3 dB

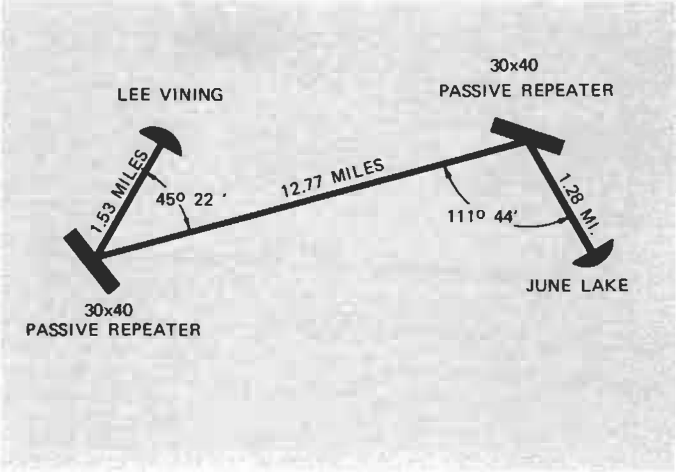
– 39.5 dBm Received Signal Level

– 79.0 dBm FM Improvement Threshold
– 39.5 dBm Received Signal

39.5 dB Fade Margin



Efficient use of two passives in one microwave link for Continental Telephone of California.



2GHz SYSTEM
72 VOICE CHANNEL CALCULATIONS

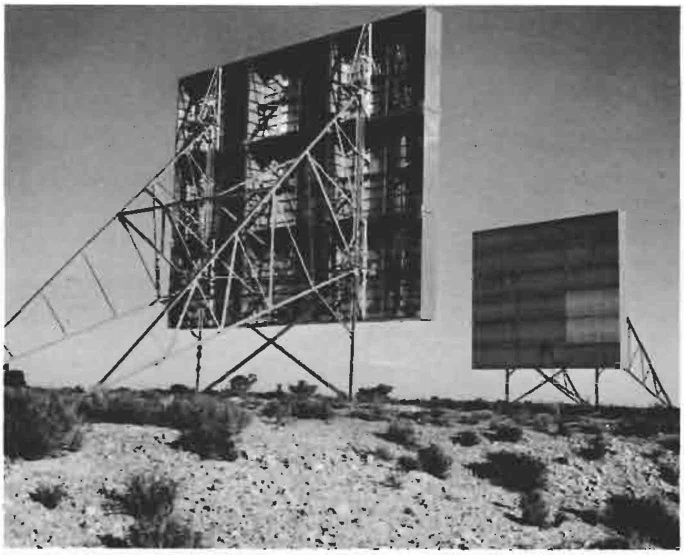
GAINS

Transmitter	+ 33.0 dBm
Passive Repeater 30 x 40	96.1 dB
Passive Repeater 30 x 40	91.8 dB
Antenna 10′	34.0 dB
Antenna 10′	34.0 dB
	+288.9 dB

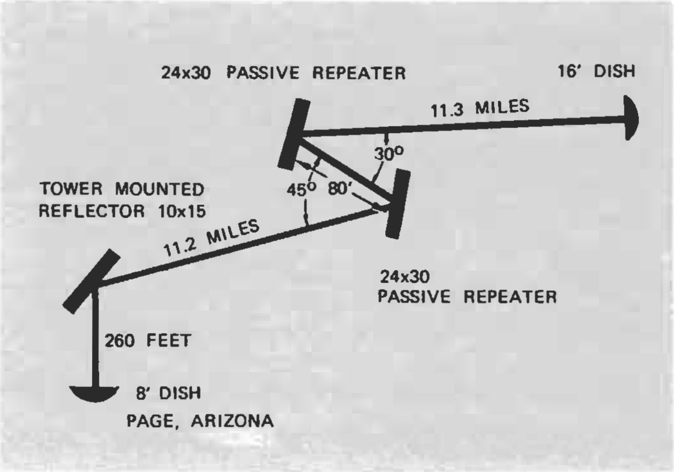
LOSSES

105.4 dB	1.28 Miles
107.0 dB	1.53 Miles
124.4 dB	12.77 Miles
8.9 dB	Equip. and Waveguide
-346.7 dB	
+288.9 dB	
-57.8 dBm	Calculated Received Signal Level
- 58.5 dBm	Measured Received Signal Level
-92.0 dBm	FM Improvement Threshold
- 58.5 dBm	Received Signal
33.5 dB	Fade Margin

Noise, worst slot, 24.2 dBrnCO



Another arrangement of a double passive repeater. This one is almost exactly midpath with one path 11.2 miles long, the other 11.3 miles long. It was installed for Mountain Bell of Arizona.



6 GHz SYSTEM
300 VOICE CHANNEL CALCULATIONS

GAINS

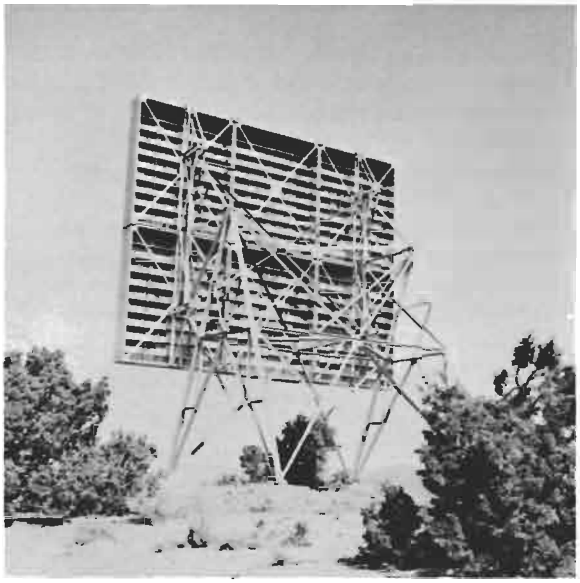
Transmitter	+30.0 dBm
Antenna 16′	47.0 dB
Reflector 10x15 and Antenna 8′	41.6 dB
Double 24x30 Passive	110.0 dB
	+228.6 dB

LOSSES

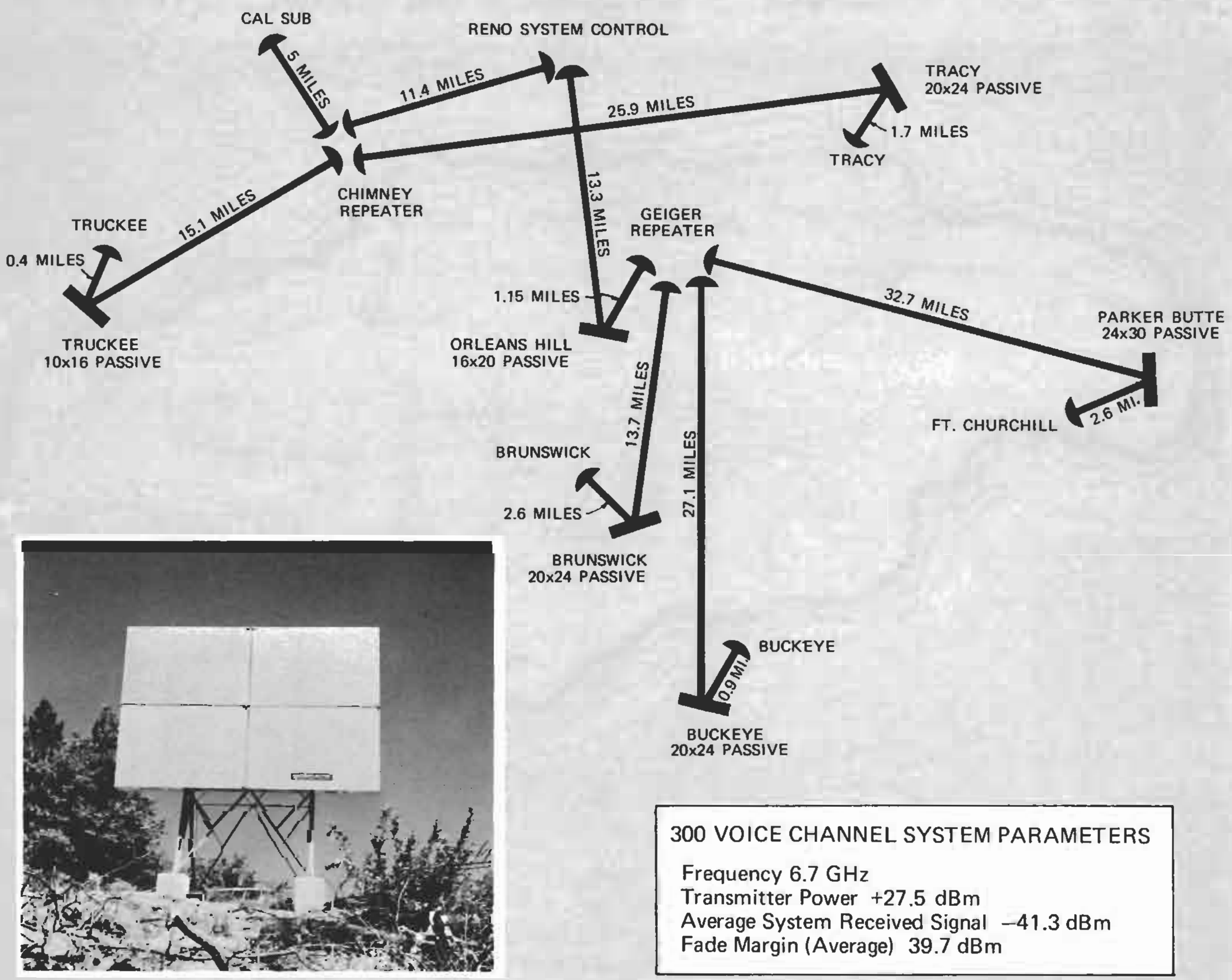
134.0 dB	11.2 Miles
134.0 dB	11.3 Miles
4.0 dB	Waveguide and Coax
1.0 dB	Double Passive Repeater
– 273.0 dB	
+ 228.6 dB	
–44.4 dBm	Received Signal Level
– 81.0 dBm	FM Improvement Threshold
– 44.4 dBm	Received Signal
36.6 dBm	Fade Margin

The terrain around Reno, Nevada consists of desert mountains and flats and the Sierra Nevada mountain range. There are no line-of-sight paths from Sierra Pacific Power Company's Central Control facility, in Reno, to any of their substations or generating plants. Direct line of sight and proper Fresnel zone clearance exists to only one of the two active repeaters in the system. Only one of the six active terminals has a direct path to its associated active repeater. Yet, the system provides 39.7 dB plus Fade Margins to the two active hub repeaters and to the six active terminals in the system.

This accomplishment was made possible through the application of passive repeaters. The Sierra Pacific Power Company decided they wanted a microwave system which was inexpensive and easy to maintain. To keep the expense of installation down meant using as few active repeaters as necessary to accomplish the needs of the system. By using the passive repeater, which is less expensive than an active repeater, future operating costs were reduced as the passives require no power to operate and no access roads.



Three 20x24 passives of this type were used in the system. Passive sizes will vary in one system due to individual path requirements,

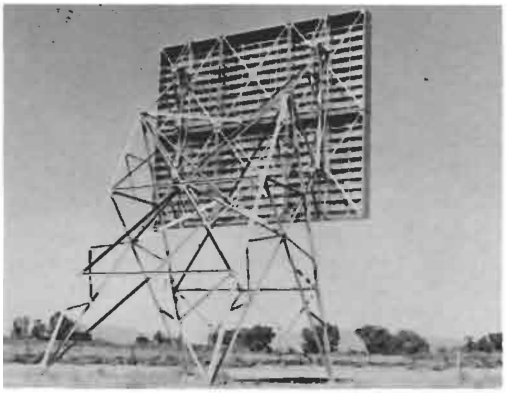


300 VOICE CHANNEL SYSTEM PARAMETERS

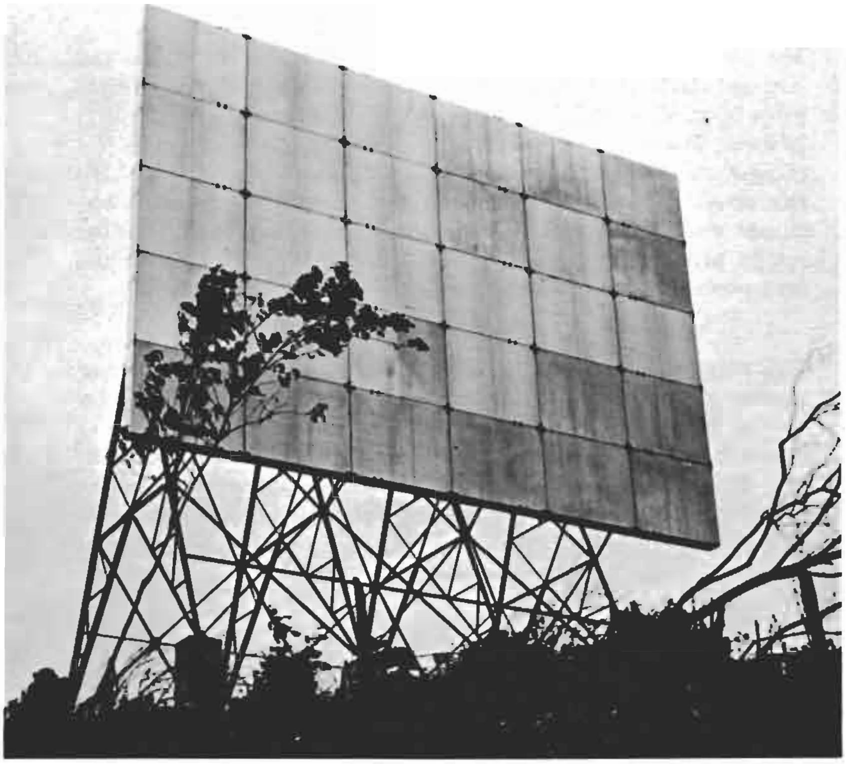
Frequency 6.7 GHz
Transmitter Power +27.5 dBm
Average System Received Signal −41.3 dBm
Fade Margin (Average) 39.7 dBm

A 16x20 passive of the type used at Orleans Hill.

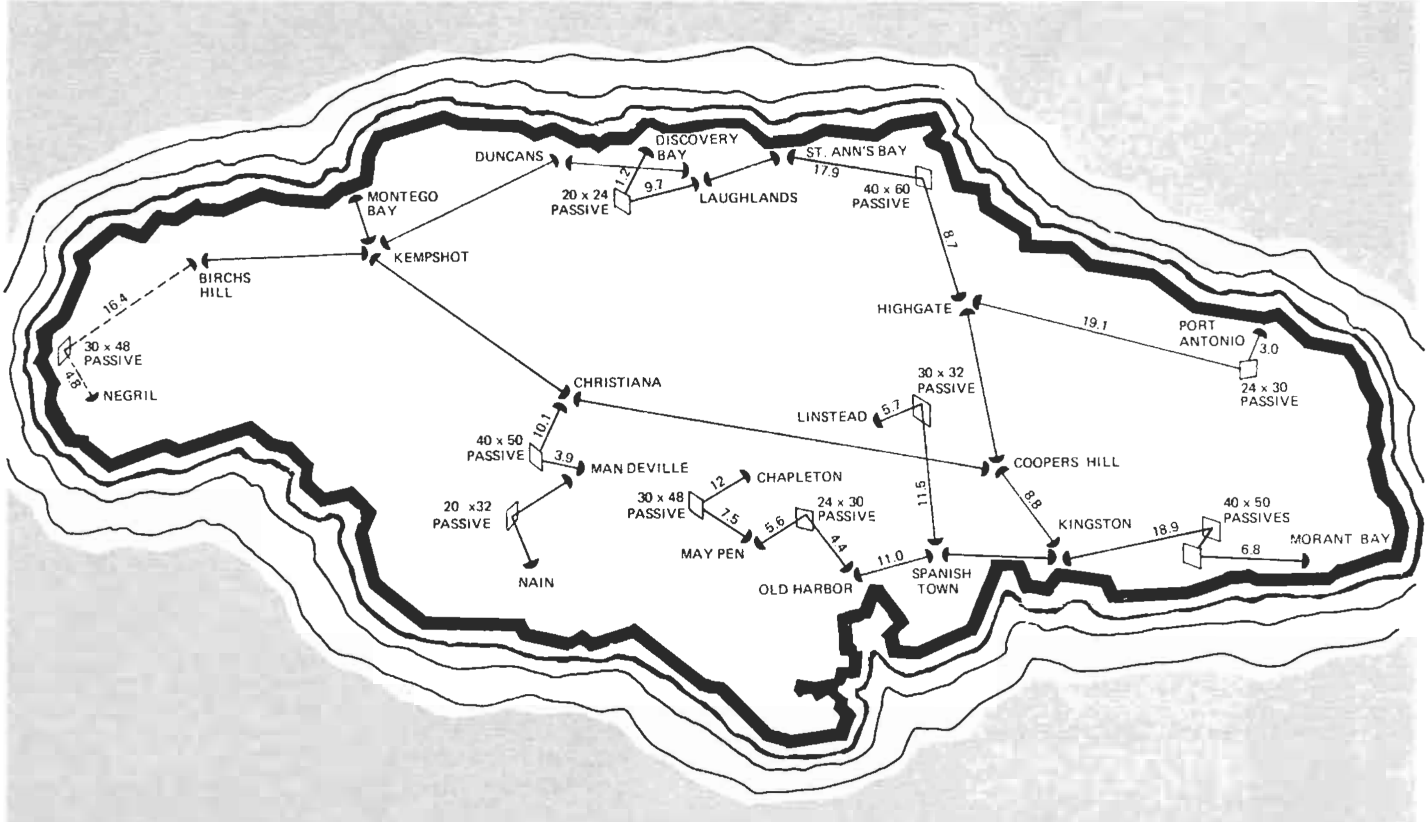
The ruggedness of Jamaican terrain and the lack of existing power and access facilities to many of the islands' peaks made the use of passive repeaters a "natural" for a new 960 voice channel microwave system installed by Collins Radio for Jamacia Telephone Company. Significant savings in operating and maintenance costs can be realized in any size system by using passive repeaters. The "one-time" cost of a passive is relatively small compared to the continual cost of operating and maintaining an active repeater site.



A 20x24, similar to this, is the smallest passive in the system.



Microflect's 40x60, the largest in the system, is also the largest model manufactured.



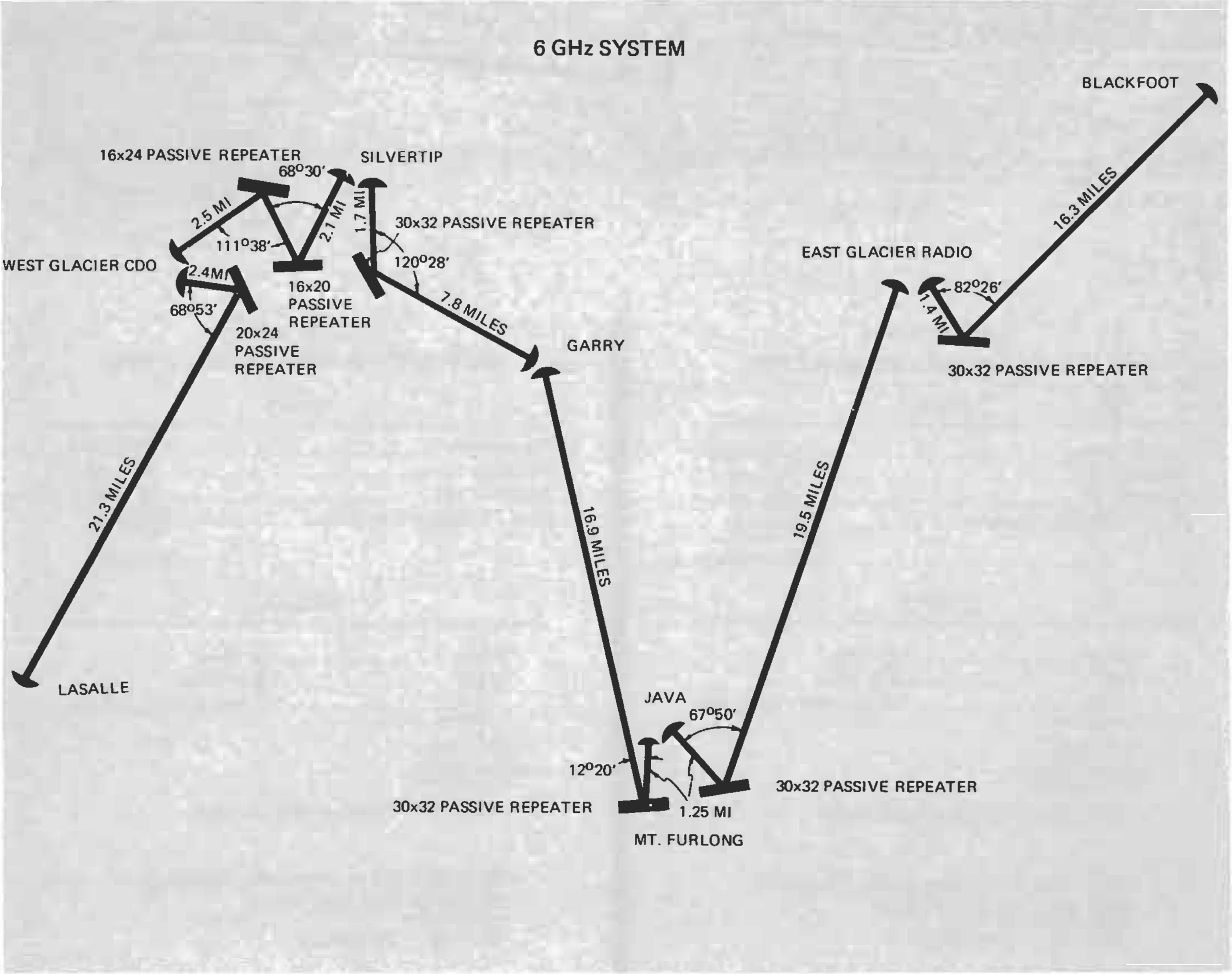
Jamacia Telephone Co. (Continental Telephone System)

SYSTEM PARAMETERS

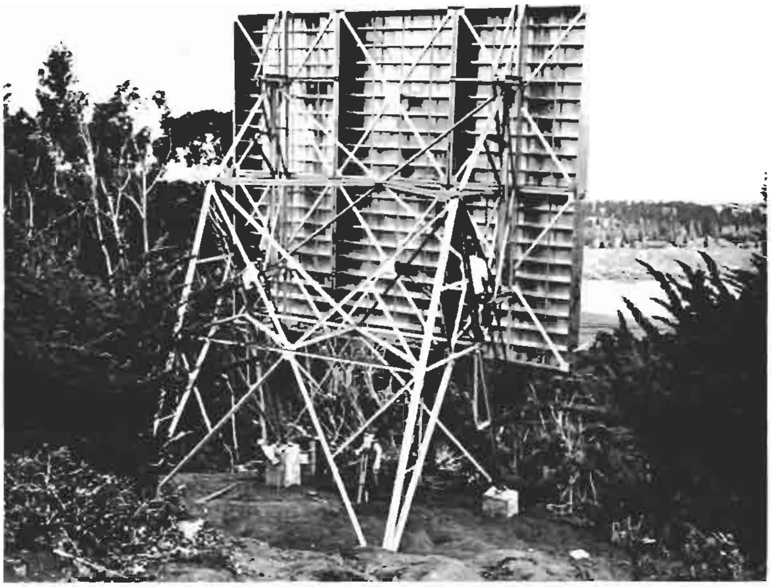
TRANSMIT POWER +30dBm
MICROWAVE BAND 6GHz
RECEIVED SIGNAL LEVEL (AVERAGE) −36dBm
LOADING +14.8dBmO for 960 Voice channels SSBSC

This 30 x 32 passive is located between Garry and Silvertip.

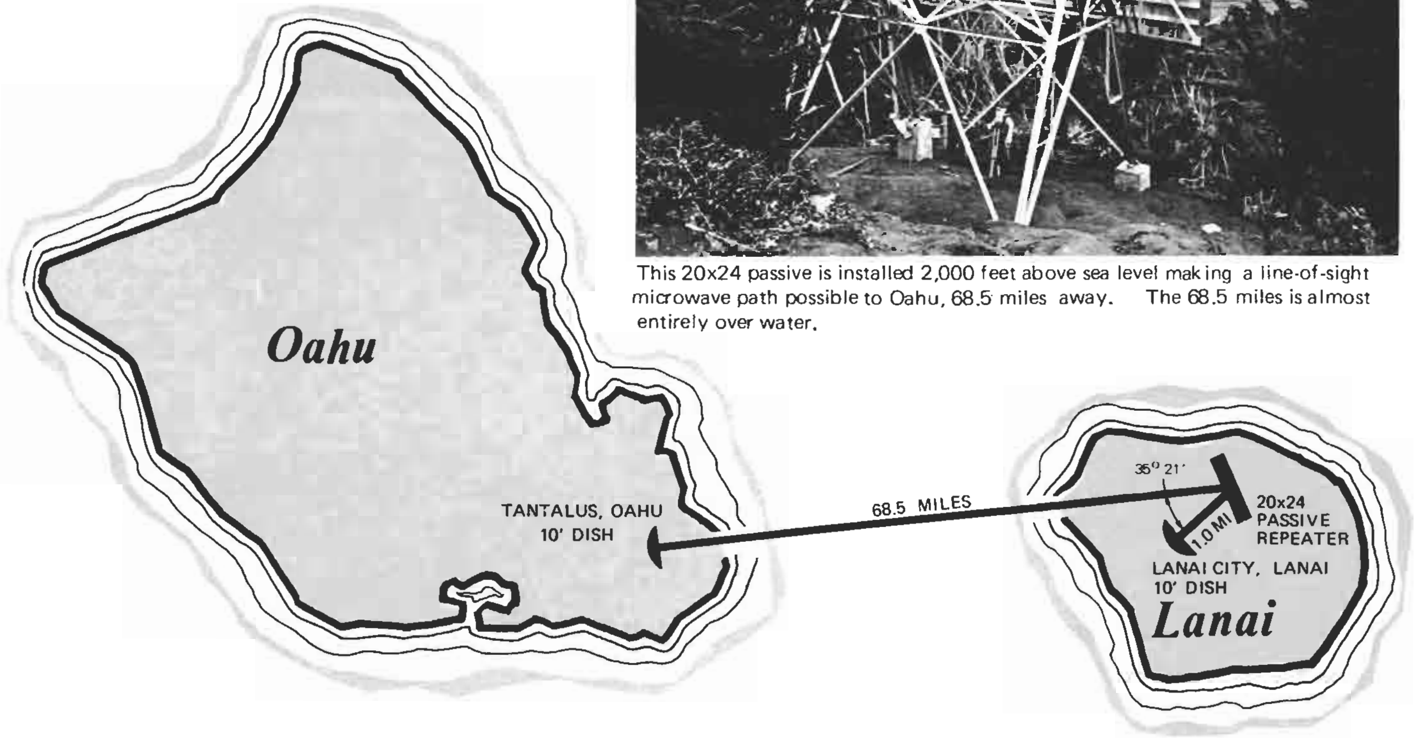
This system was installed in Glacier National Park for Mountain States Telephone Company. A low elevation system, through narrow mountain passes would have provided no more than a few miles line-of-sight between active stations. The application of passive repeaters allowed the microwave paths to be "elevated" to mountain tops which greatly increased path lengths while still allowing active stations to be located near "all-year" roads. The passives do not require maintenance and were therefore located on the most advantageous peaks regardless of accessibility. Helicopters were used on six of the seven passive sites to fly in Microflect erection crews and the passive repeater materials. Vertical face angles of some of the passives in relation to short paths and extreme differences in elevations exceeded normal conditions. The interface structure on the rear legs of the passive shown at left is an example of how this type of problem can be easily solved. There is a 3,411 foot difference in 1.7 miles in this passive application.



The Hawaiian Telephone Company revised their 2GHz system by increasing the frequency to 4GHz. Both calculations are shown below. There was no change required in the passive since they are not sensitive to frequency. In some installations the same passive has been used for two or more frequencies simultaneously.



This 20x24 passive is installed 2,000 feet above sea level making a line-of-sight microwave path possible to Oahu, 68.5 miles away. The 68.5 miles is almost entirely over water.



2 GHz SYSTEM
72 VOICE CHANNEL CALCULATIONS

GAINS

Transmitter	+ 37.0 dBm
Parabola 10′	34.2 dB
Parabola 10′	34.2 dB
20 x 24 Passive Repeater	87.5 dB
	+ 192.7 dBm

LOSSES

102.6	1.0 Mile
139.3	68.5 Miles
3.5	Transmission Line, etc.

−245.4 dB
+192.7 dBm

- 52.7 dBm Received Signal Level

- 87.0 dBM	FM Improvement Threshold
- 52.7 dBm	Received Signal
34.3 dB	Fade Margin

4 GHz SYSTEM
300 VOICE CHANNEL CALCULATIONS

GAINS

Transmitter	+ 33.0 dBm
Parabola 10′	39.3 dB
Parabola 10′	39.3 dB
20 x 24 Passive Repeater	100.0 dB
	+211.6 dBm

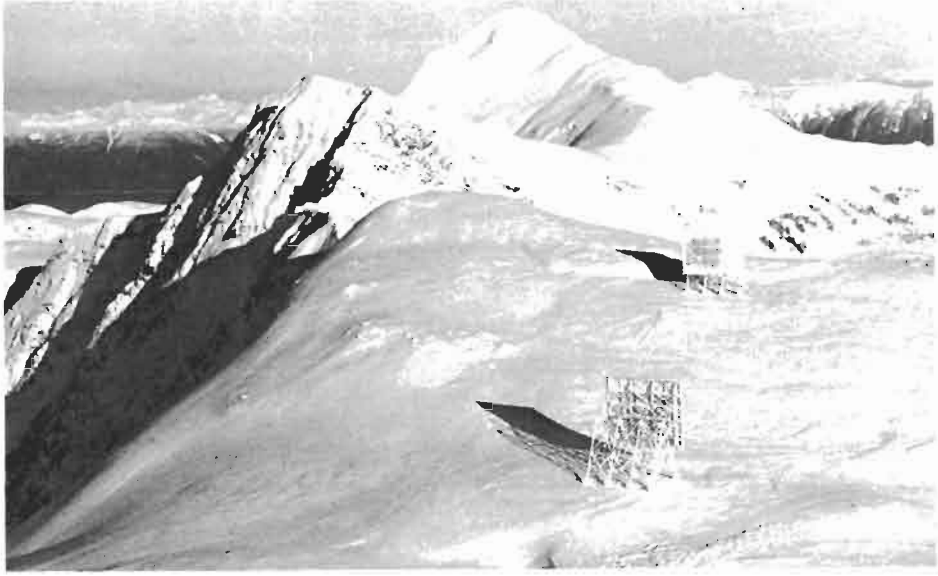
LOSSES

108.6	1.0 Mile
145.3	68.5 Miles
3.5	Transmission Line, etc.

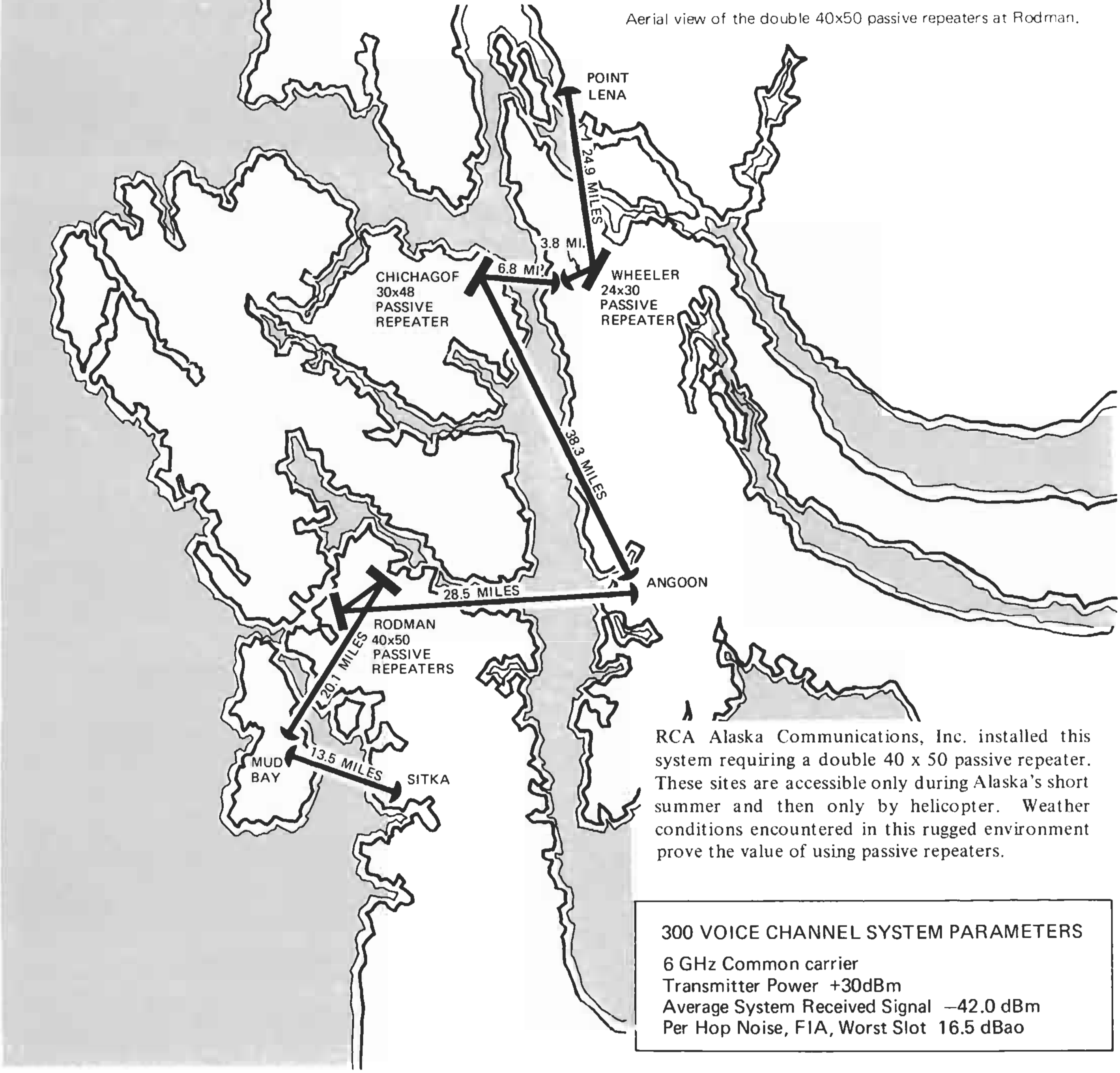
− 257.4 dB
+ 211.6 dBm

- 45.8 dBm Received Signal Level

- 86.5 dBm	FM Improvement Threshold
- 45.8 dBm	Received Signal
40.7 dB	Fade Margin



Aerial view of the double 40x50 passive repeaters at Rodman.



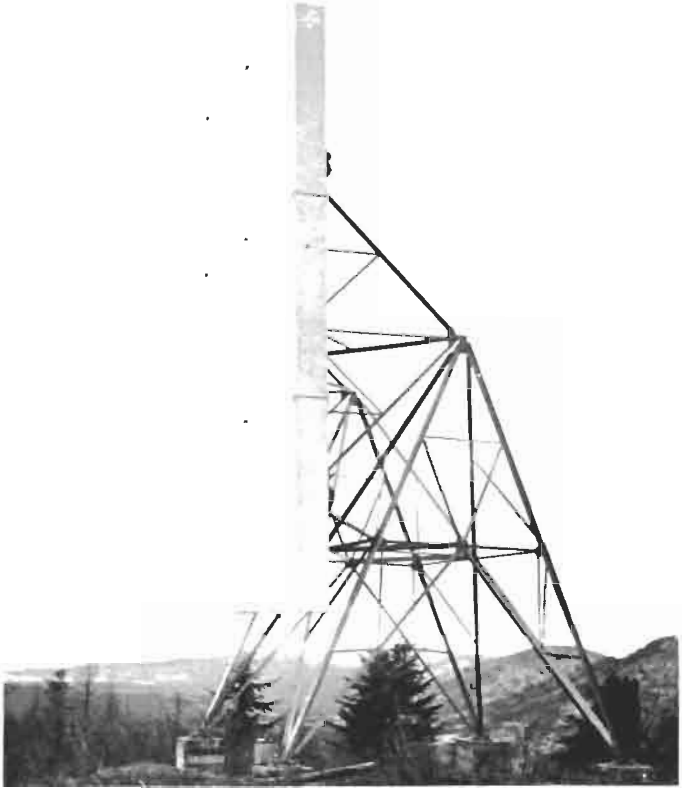
RCA Alaska Communications, Inc. installed this system requiring a double 40 x 50 passive repeater. These sites are accessible only during Alaska's short summer and then only by helicopter. Weather conditions encountered in this rugged environment prove the value of using passive repeaters.

300 VOICE CHANNEL SYSTEM PARAMETERS

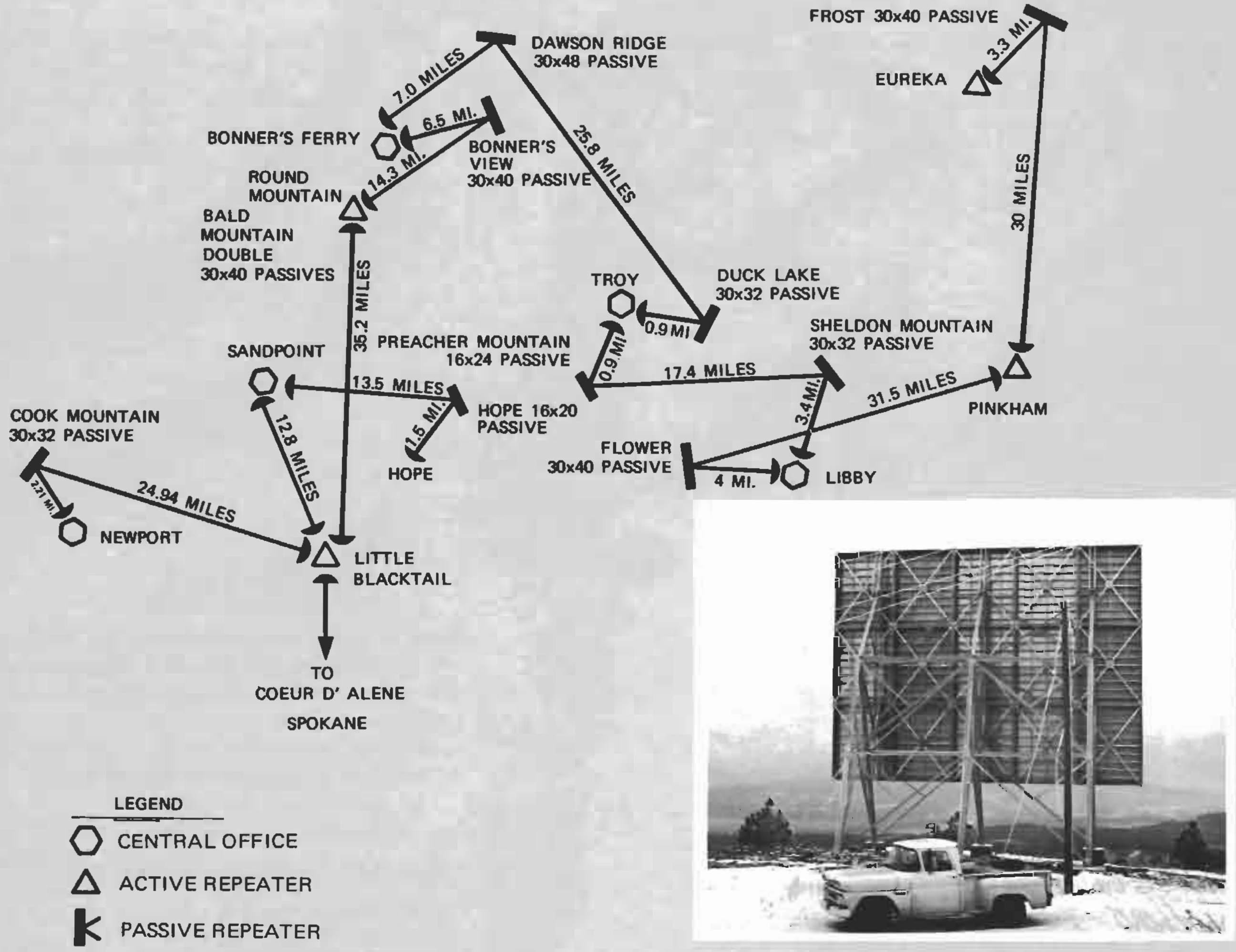
6 GHz Common carrier
Transmitter Power +30dBm
Average System Received Signal –42.0 dBm
Per Hop Noise, F1A, Worst Slot 16.5 dBao

Many microwave systems that were engineered ten years ago used the active repeater to tie the system spur terminals and backbone stations together. Some of these systems are being planned for rehabilitation in the next few years and many will apply new passive repeater techniques to make the system more economical and reliable.

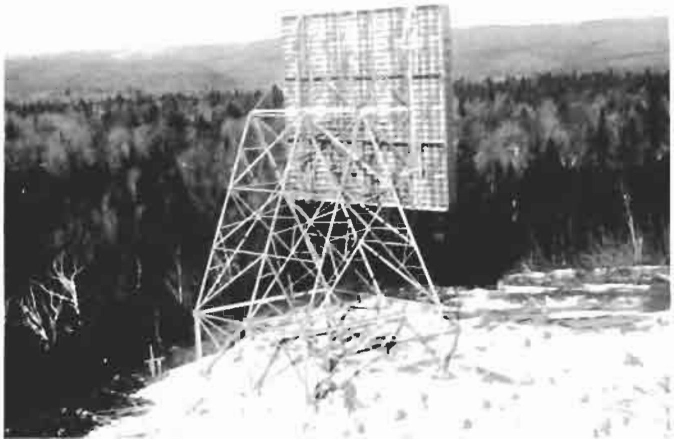
One major change involves a change in engineering approach. For example, consider your spur terminals as repeaters. Why not?........Half the repeater is already there in the form of the terminal gear. Then, connect the terminal repeaters together by way of passive repeaters. One major independent Telephone Company did this in a general upgrading of one of their systems as shown below. One existing and one planned active mountain top repeater was eliminated. Maintenance personnel safety was increased and operating costs reduced.



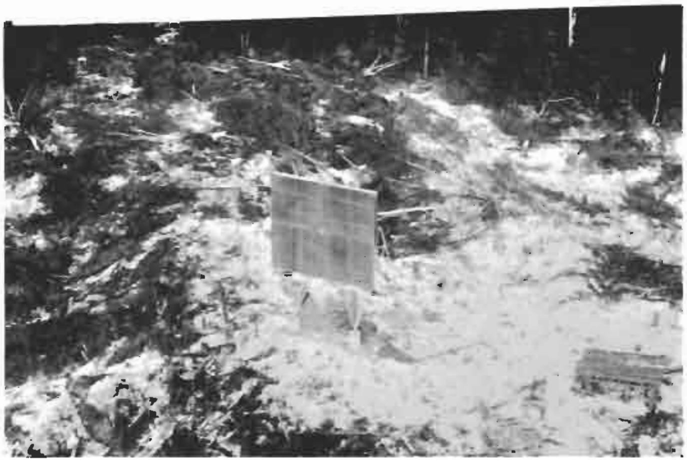
A 30x32 passive repeater installation.



This 30x40 passive is located at Bonner's View.



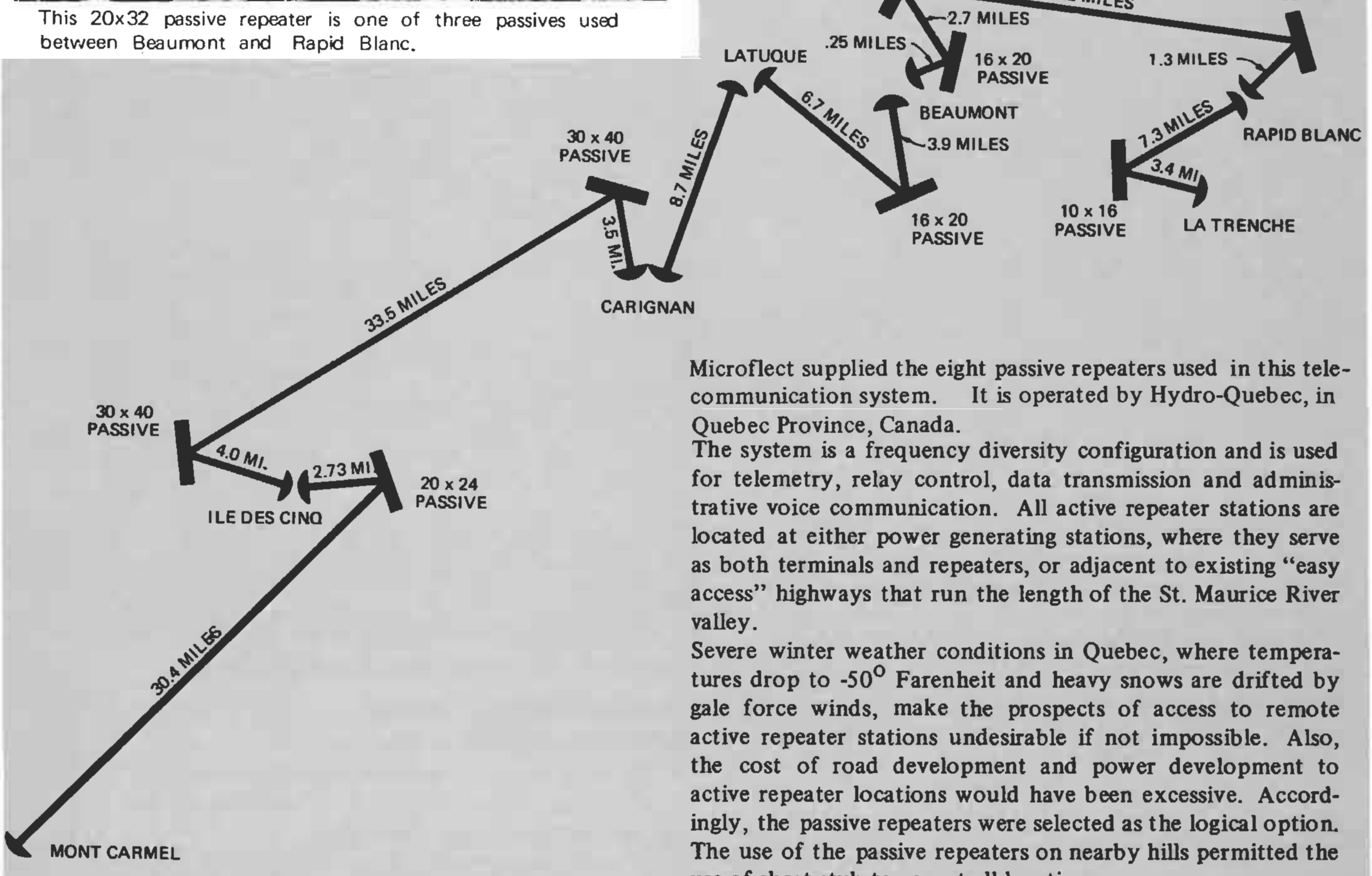
This 30x40 passive repeater redirects the signal from Ile Des Cinq 4.0 miles away to another 30 x 40 passive 33.5 miles away, which redirects the signal another 3.5 miles to Carignan.



A 16x20 passive repeater is installed in the path between La Tuque and Beaumont.

This 20x32 passive repeater is one of three passives used between Beaumont and Rapid Blanc.

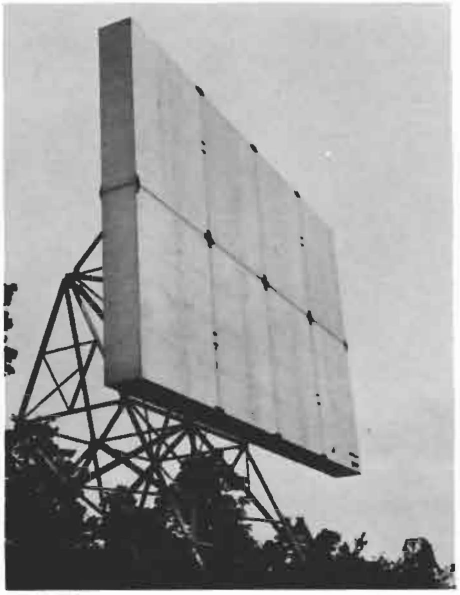
SYSTEM PARAMETERS
TRANSMIT POWER +28.5dBm Average
MICROWAVE BAND 7.5 GHz
RECEIVED SIGNAL LEVEL (AVERAGE) –42.0dBm
WORST CHANNEL PERFORMANCE 27dBrnCO end to end
LOADING +7.3dBmO for 120 Voice channels



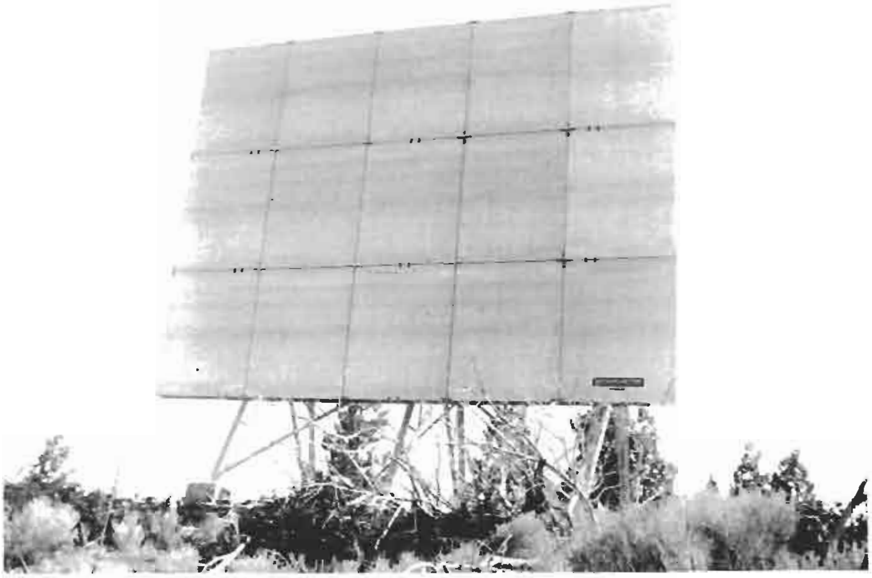
Microflect supplied the eight passive repeaters used in this telecommunication system. It is operated by Hydro-Quebec, in Quebec Province, Canada.

The system is a frequency diversity configuration and is used for telemetry, relay control, data transmission and administrative voice communication. All active repeater stations are located at either power generating stations, where they serve as both terminals and repeaters, or adjacent to existing "easy access" highways that run the length of the St. Maurice River valley.

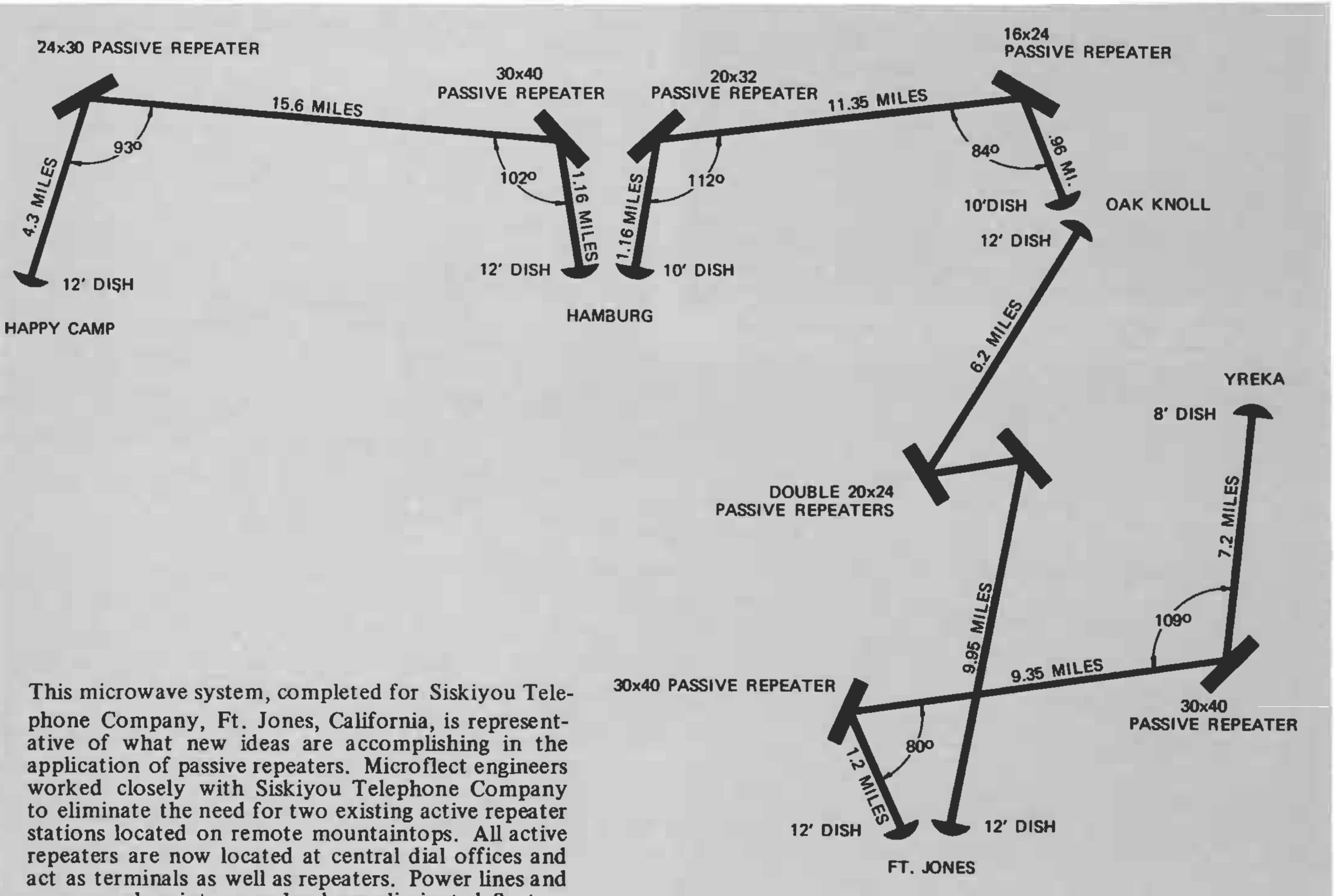
Severe winter weather conditions in Quebec, where temperatures drop to -50° Farenheit and heavy snows are drifted by gale force winds, make the prospects of access to remote active repeater stations undesirable if not impossible. Also, the cost of road development and power development to active repeater locations would have been excessive. Accordingly, the passive repeaters were selected as the logical option. The use of the passive repeaters on nearby hills permitted the use of short stub towers at all locations.



A 20x32 passive was used between Hamburg and Oak Knoll.



Three 30x40 passives were used in this system.



This microwave system, completed for Siskiyou Telephone Company, Ft. Jones, California, is representative of what new ideas are accomplishing in the application of passive repeaters. Microflect engineers worked closely with Siskiyou Telephone Company to eliminate the need for two existing active repeater stations located on remote mountaintops. All active repeaters are now located at central dial offices and act as terminals as well as repeaters. Power lines and access road maintenance has been eliminated. System costs were reduced and reliability increased by elimanating power line and access road maintenance problems and by reducing the amount of active radio equipment used.

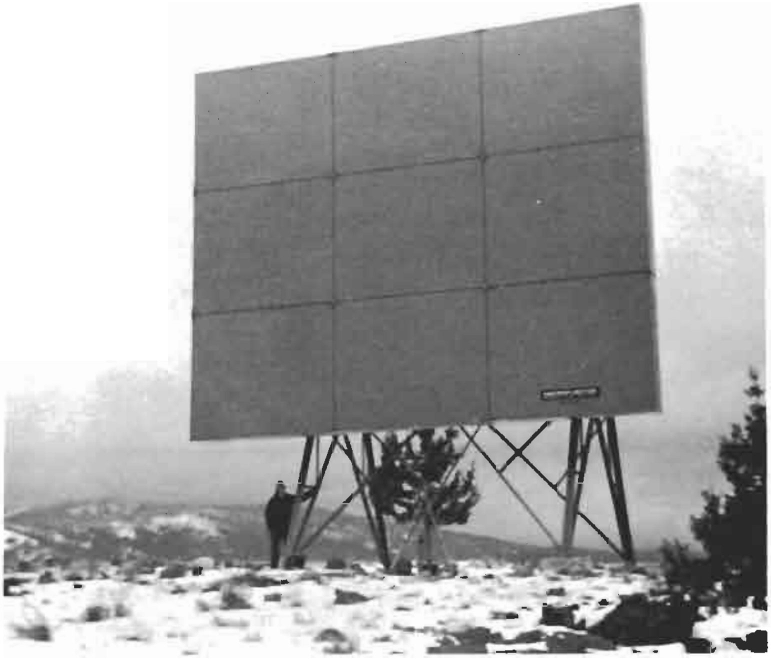
600 VOICE CHANNEL SYSTEM PARAMETERS

TRANSMIT POWER +31dBm
MICROWAVE BAND 6 GHz
RECEIVED SIGNAL LEVEL(AVERAGE) −38dBm
WORST SLOT PERFORMANCE 17 dBaO end to end
FADE MARGIN 43db AVERAGE

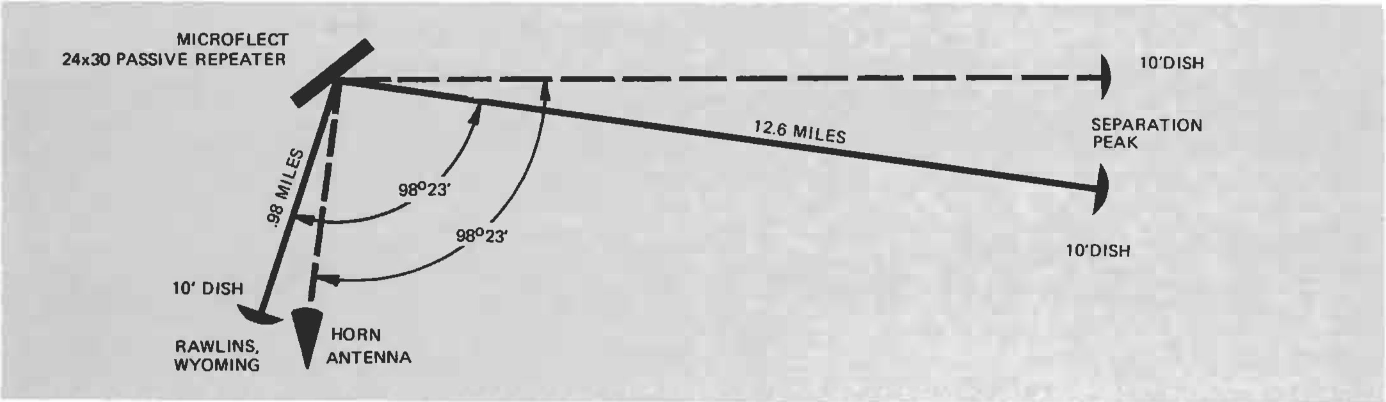
Passive Repeaters have a major advantage over active repeaters from the ecologist's standpoint. It isn't necessary to gouge roads and power line rights of way to the repeater site. The Passive Repeater requires negligible maintenance and can be visited by horseback, by foot, or by helicopter when necessary.

From the cost analyst's standpoint, the Passive Repeater is almost always the least expensive to install and is the least expensive to operate.

From an operational standpoint, the Passive Repeater is ideal since it offers both low maintenance and high reliability.



Two separate microwave paths use this passive simultaneously in an application for Mountain Bell of Wyoming.



2 GHz SYSTEM
240 VOICE CHANNEL CALCULATIONS

GAINS

Transmitter	+33.0 dBm
10' Antenna	33.2 dB
10' Antenna	33.2 dB
24x30 Passive	88.0 dB
	+187.4 dB

LOSSES

102.9 dB	.98 Mile Path
125.1 dB	12.6 Mile Path
1.9 dB	Coax

−229.9 dB (Total Losses)
+187.4 dB (Total Gains)

− 42.5 dBm Received Signal

− 81.0 dBm FM Improvement Threshold
− 42.5 dBm Received Signal

38.5 dBm Fade Margin

6GHz SYSTEM
600 VOICE CHANNEL CALCULATIONS

GAINS

Transmitter	+20.0 dBm
10' Antenna	43.1 dB
10' Horn	43.1 dB
24x30 Passive	107.0 dB
	+213.2 dB

LOSSES

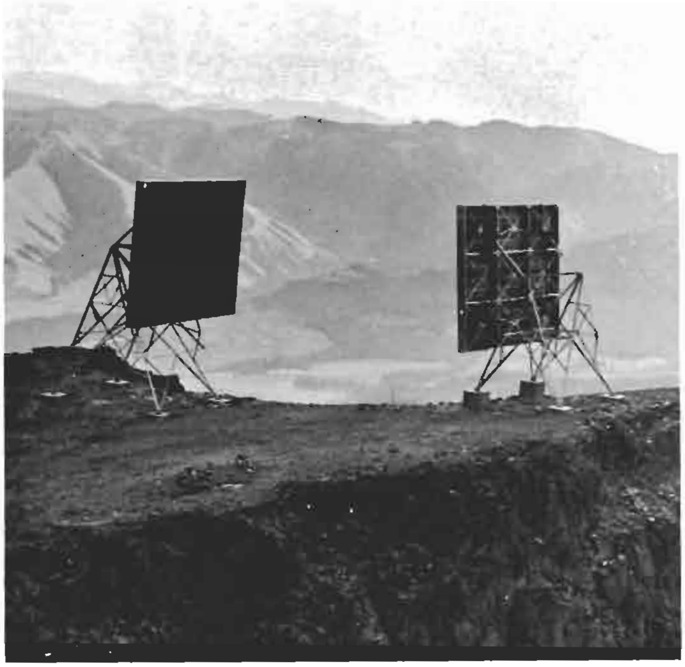
112.0 dB	.98 Mile Path
134.2 dB	12.6 Mile Path
6.4 dB	Waveguide

−252.6 dB (Total Losses)
+213.2 dB (Total Gains)

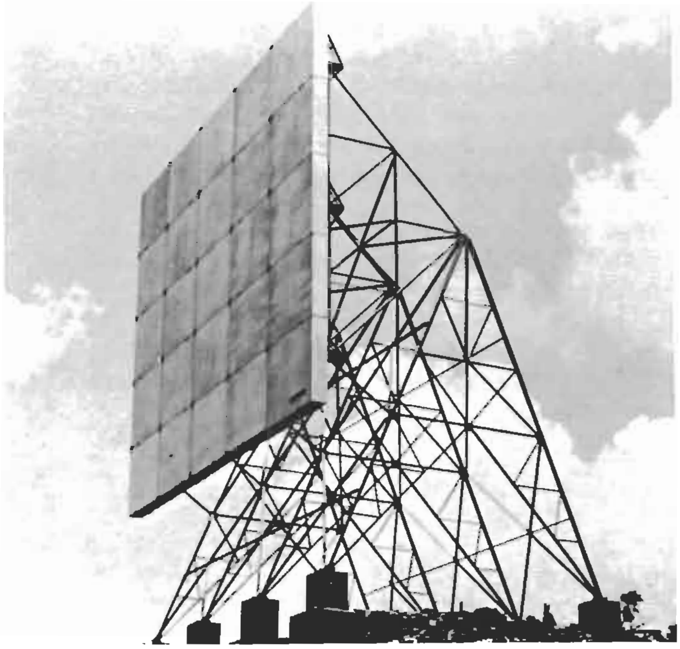
− 39.4 dBm Received Signal

− 81.0 dBm FM Improvement Threshold
− 39.4 dBm Received Signal

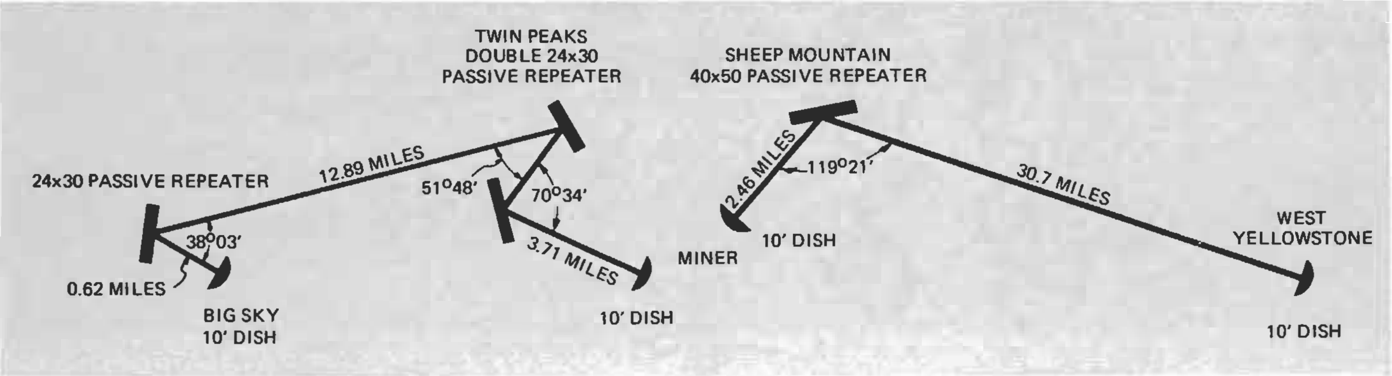
41.6 dB Fade Margin



This double 24x30 passive repeater provides 119 dB gain in the critical link of the Big Sky resort area system.



The 40x50 on Sheep Mountain provides proper path clearances between Miner and West Yellowstone and makes "passable" otherwise impassable mountains.



11 GHz SYSTEM
600 VOICE CHANNEL CALCULATIONS

GAINS

Transmitter..+26.0 dBm
Antenna 10'..47.0 dB
Antenna 10'..47.0 dB
24x30 Passive Repeater (Near Field)........4.0 dB
24x30 Double Passive..........................119.0 dB
+233.0 dB

LOSSES

−129.0 dB.......................3.71 Mile Path
−139.8 dB.......................12.89 Mile Path
−4.5 dB........................Waveguide and Hardware
−1.0 dB........................Double Passive Coupling
−274.3 dB (Total Losses)
+233.0 dB (Total Gains)
−33.0 dBm Measured Received Signal
−31.3 dBm Calculated Received Signal

−80.5 FM Improvement Threshold
−33.0 dBm
47.5 dB Fade Margin

Idle plus intermod noise, worst slot=20 dBrnCo
For 600 channel loading, without emphasis.

6 GHz SYSTEM
600 VOICE CHANNEL CALCULATIONS

GAINS

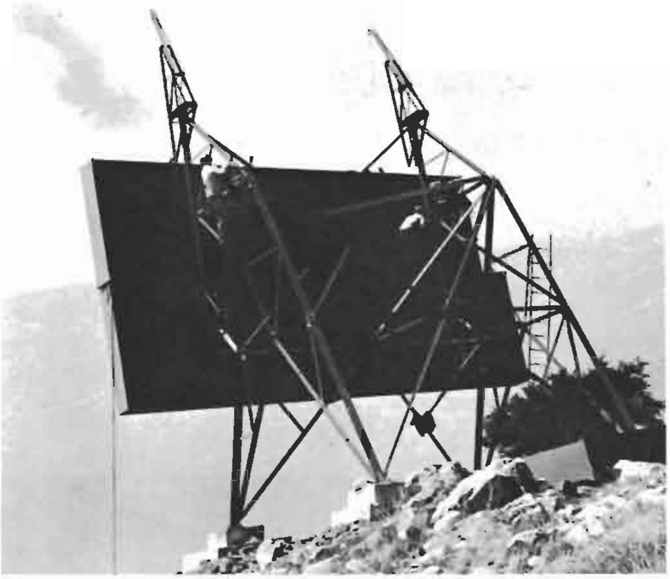
Transmitter...+33.0 dBm
Two 10' Antennas................................86.0 dB
+119.0 dB

LOSSES

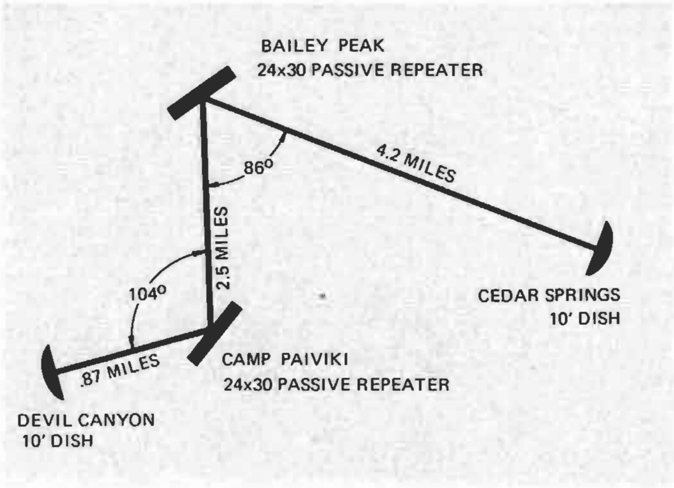
−6.5 dB...................... Near Field Loss
−142.1 dB..................... 30.7 Mile Path
−6.6 dB..................... Waveguide and Equipment
−155.2 dB (Total Losses)
+119.0 dB (Total Gains)
−36.2 dBm Received Signal Level

−79.0 dBm FM Improvement Threshold
−36.2 dBm
42.8 dB Fade Margin

Noise, worst slot=22dBrnCO



The passive being erected for General Telephone of California is one of the 24x30 passives in the system shown below.



2GHz SYSTEM
FOR TELEMETRY CHANNELS

GAINS

Transmitter	+34.0 dBm
Antenna 10'	34.5 dB
Antenna 10'	34.5 dB
24x30 Passive Repeater	89.0 dB
24x30 Passive Repeater	90.3 dB
	+282.3 dB

LOSSES

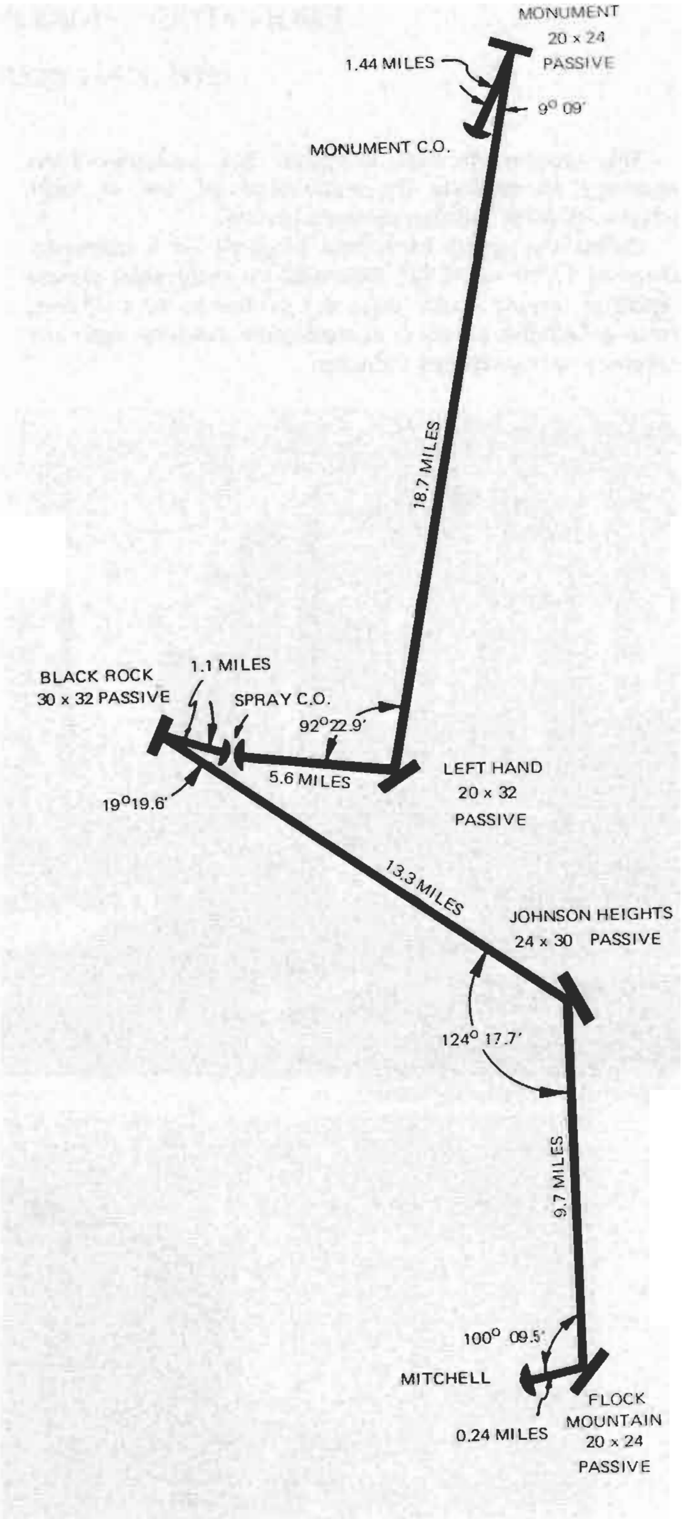
−102.2 dB	0.87 Miles
−111.3 dB	2.5 Miles
−115.8 dB	4.2 Miles
−4.0 dB	Coax

−333.3 dB (Total Losses)
+282.3 dB (Total Gains)

−51.0 dBm Received Signal Level

−89.0 dB FM Improvement Threshold
−51.0 dBm

38.0 dB Fade Margin
Measured Power Noise = 19.0 dBrncO



300 VOICE CHANNEL SYSTEM PARAMETERS

Frequency	11GHz
Transmitter power	+28 dBm
Received signal level(Average)	−40 dBm

System installed for Blue Mountain Telephone Co. of Oregon

CHAPTER II

PATH CALCULATIONS FOR MICROWAVE SYSTEMS UTILIZING PASSIVE REPEATERS

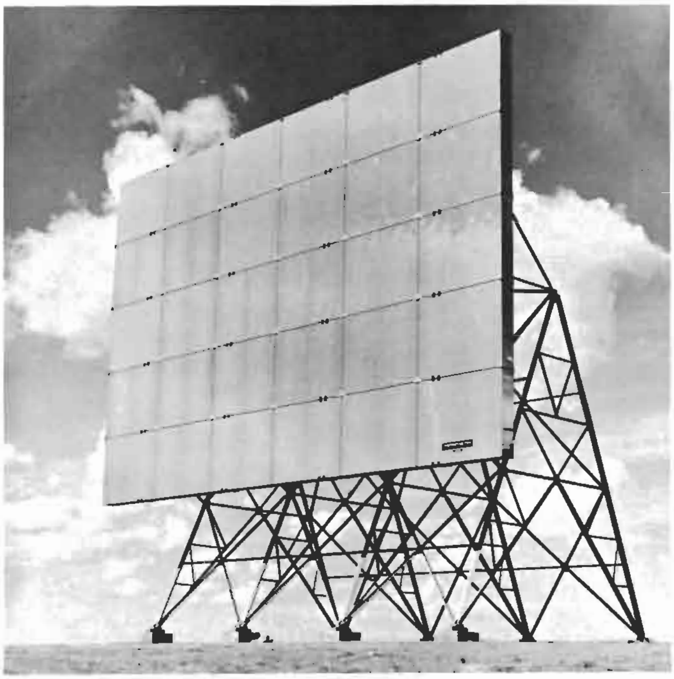
This chapter provides technical data and procedures necessary to calculate the performance of line-of-sight microwave paths utilizing passive repeaters.

Curves and charts have been prepared for a frequency range of 1.780 to 14.825 GHz and for rectangular passive repeaters varying in size from 8 x 10 feet to 40 x 60 feet. Data is included to cover commercially available parabolic antennas, waveguide and radomes.

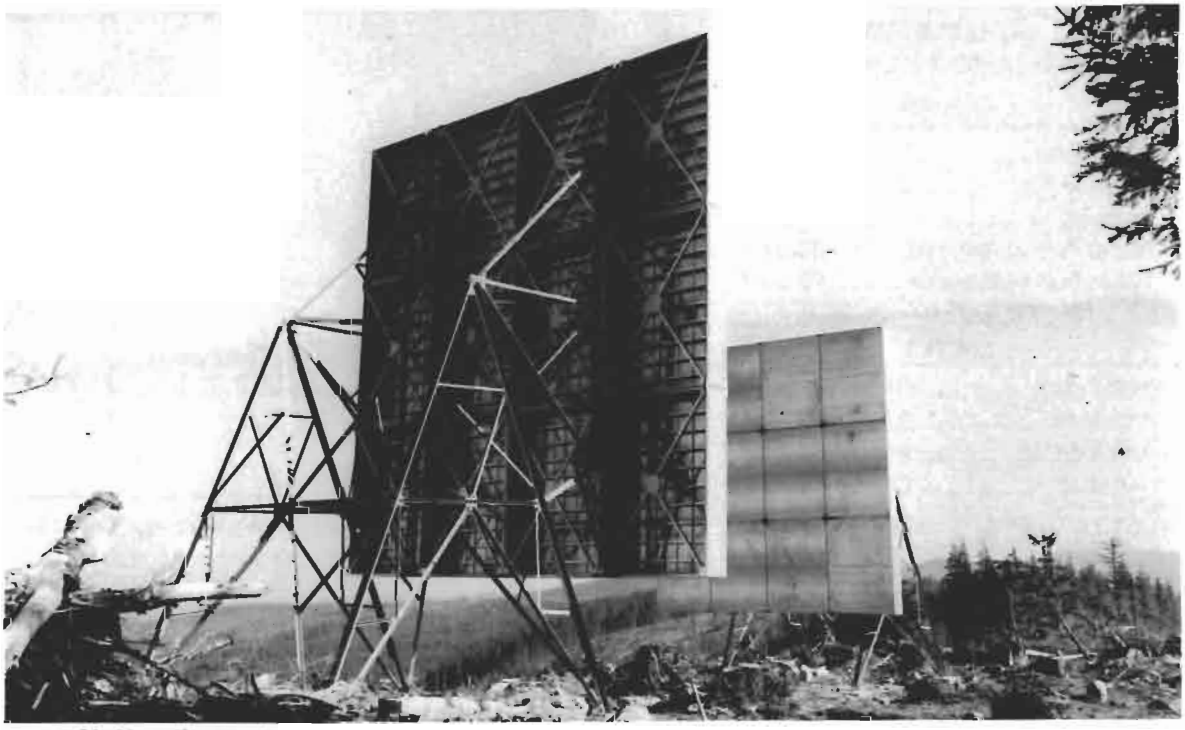
Example calculations are superimposed on worksheets to provide comparison figures and to illustrate the use of the charts and graphs.

By copying the worksheets on an office copier several combinations of figures can be tried to select the system for desired performance and favorable economics with respect to equipment combinations.

Building mounted passive repeater

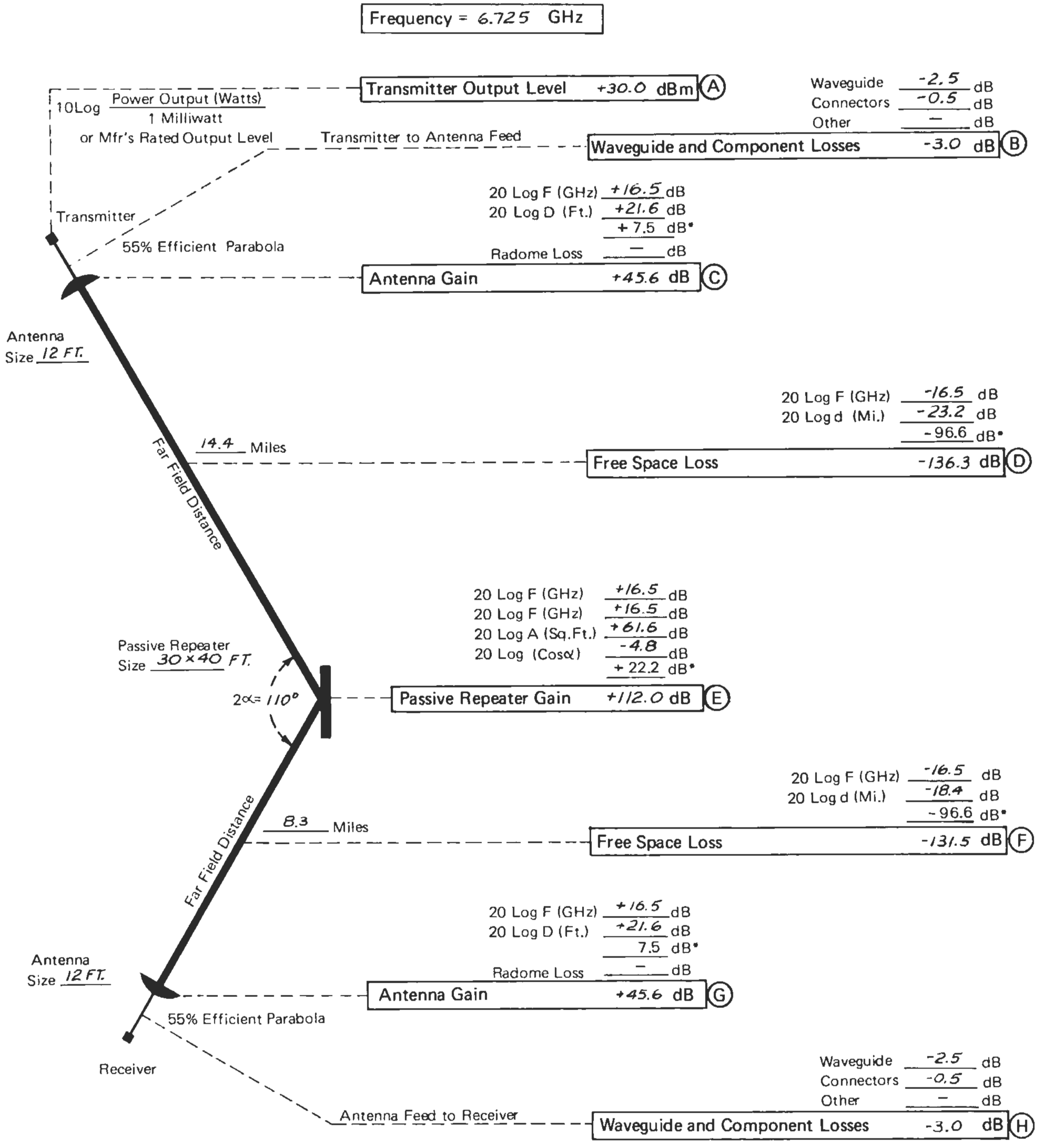


Single 40x60 passive repeater



Double 30x32 passive repeaters

This example shows a typical passive repeater application with both antennas in the far field. The values for the gain of the antennas and the passive repeater and the attenuation of the two paths are calculated rather than selected from charts and graphs. This is done to illustrate the calculation of the values shown on the charts and included in this text. The same path is evaluated on page 27using the charted figures for comparison. It is not intended that this example be used as a work sheet.



Frequency = *6.725* GHz

$10 \text{Log} \frac{\text{Power Output (Watts)}}{\text{1 Milliwatt}}$ or Mfr's Rated Output Level

Transmitter Output Level *+30.0* dBm Ⓐ

Transmitter to Antenna Feed

Waveguide *-2.5* dB
Connectors *-0.5* dB
Other *—* dB

Waveguide and Component Losses *-3.0* dB Ⓑ

20 Log F (GHz) *+16.5* dB
20 Log D (Ft.) *+21.6* dB
+ 7.5 dB*
Radome Loss *—* dB

Antenna Gain *+45.6* dB Ⓒ

20 Log F (GHz) *-16.5* dB
20 Log d (Mi.) *-23.2* dB
- 96.6 dB*

Free Space Loss *-136.3* dB Ⓓ

20 Log F (GHz) *+16.5* dB
20 Log F (GHz) *+16.5* dB
20 Log A (Sq.Ft.) *+61.6* dB
20 Log (Cosα) *-4.8* dB
+ 22.2 dB*

Passive Repeater Gain *+112.0* dB Ⓔ

20 Log F (GHz) *-16.5* dB
20 Log d (Mi.) *-18.4* dB
- 96.6 dB*

Free Space Loss *-131.5* dB Ⓕ

20 Log F (GHz) *+16.5* dB
20 Log D (Ft.) *+21.6* dB
7.5 dB*
Radome Loss *—* dB

Antenna Gain *+45.6* dB Ⓖ

Antenna Feed to Receiver

Waveguide *-2.5* dB
Connectors *-0.5* dB
Other *—* dB

Waveguide and Component Losses *-3.0* dB Ⓗ

* These values are constant from conversion of the formulas for gains and losses to logarithmic form.

COMPUTATIONAL RESULTS:

ANTENNA SYSTEM LOSS = Algebraic sum of ⒸⒹⒺⒻⒼ = *-64.6* dB

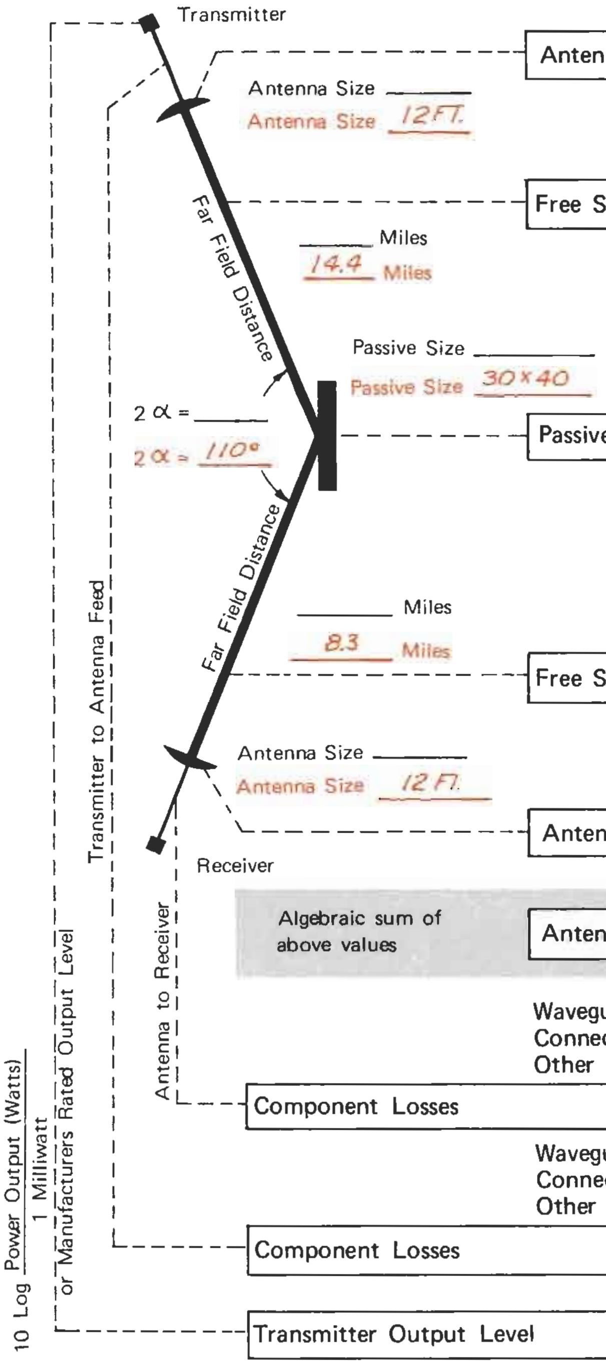
RECEIVED SIGNAL LEVEL = Algebraic sum of ⒶⒷⒸⒹⒺⒻⒼⒽ = *-40.6* dBm

FADE MARGIN = Practical receiver threshold (*-77.0dBm*) – Received signal level = *36.4* dB

SINGLE PASSIVE REPEATER, FAR FIELD OF BOTH ANTENNAS

Example of path calculation is shown in red.

Frequency	GHz	6.725 GHz



Antenna Gain	dB	+45.6 dB
Free Space Loss	dB	-136.4 dB
Passive Repeater Gain	dB	+112.1 dB
Free Space Loss	dB	-131.6 dB
Antenna Gain	dB	+45.6 dB
Algebraic sum of above values: Antenna System Loss	dB	-64.7 dB
Waveguide ______	dB	2.5 dB
Connectors ______	dB	0.5 dB
Other * ______	dB	— dB
Component Losses	dB	-3.0 dB
Waveguide ______	dB	2.5 dB
Connectors ______	dB	0.5 dB
Other * ______	dB	— dB
Component Losses	dB	-3.0 dB
Transmitter Output Level	dBm	+30.0 dBm
Antenna System Loss	dB	-64.7 dB
Algebraic sum of above values: Received Signal Level	dBm	-40.7 dBm

Threshold **	dBm	-77.0 dBm
Received Signal Level	dBm	-40.7 dBm
Fade Margin	dB	36.3 dB

* COMPONENT LOSSES

Component losses between the antenna feed and transmitter or receiver, OTHER THAN WAVEGUIDE AND CONNECTORS, may be caused by circulators, hybrids, filters, switches, combiners, or any other components that may be inserted between the transmitter or receiver terminals and the antenna feed.

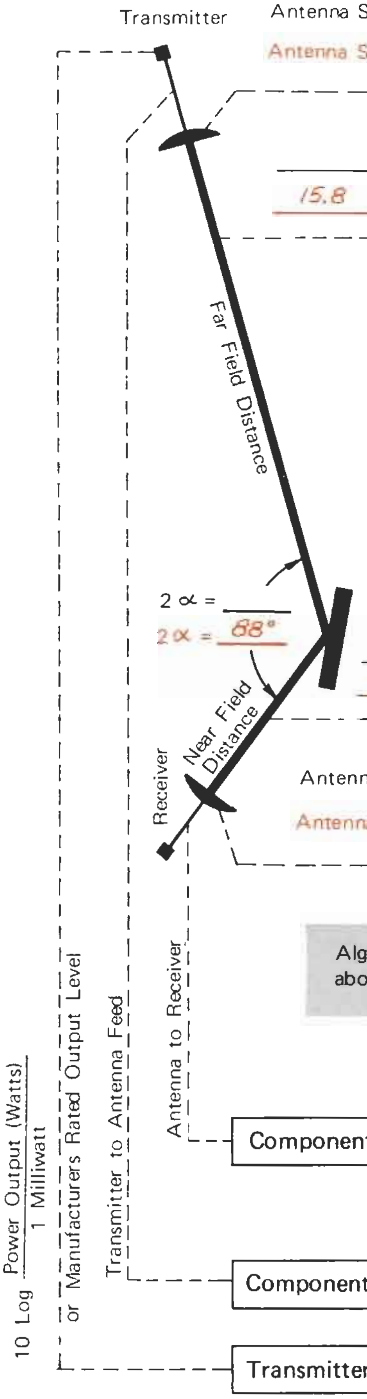
** THRESHOLD

A practical threshold for the receiver system is usually evaluated. This is often regarded as the FM Improvement Threshold, or the point where baseband signal - to - noise is 30 dB. It is the median threshold level provided by the system in the absence of fading.

SINGLE PASSIVE REPEATER, NEAR FIELD OF ONE ANTENNA

Example of path calculation is shown in red.

Frequency	GHz	11.2 GHz



Antenna Size ________

Antenna Size 10FT.

Antenna Gain	dB	+ 48.4 dB

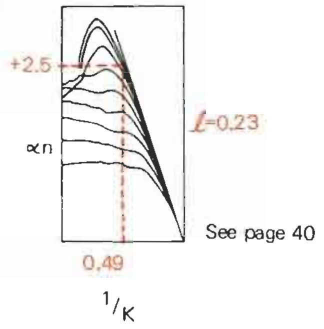
________ Miles

15.8 Miles

Free Space Loss	dB	-141.6 dB

$$1/K = \frac{(\pi)(0.9836/11.2)(0.7)(5280)}{(4)(24)(30)(\cos 88/2)}$$

$$\ell = 6\sqrt{\frac{\pi}{(4)(24)(30)(\cos 88/2)}}$$



See page 40

Passive Size ________

Passive Size 24×30

________ Miles

0.7 Miles

Near Field Loss or Gain, ∝ n=(–) OR (+)	dB	+2.5 dB

Antenna Size ________

Antenna Size 6FT.

Antenna Gain	dB	+44.0 dB

Algebraic sum of above values

Antenna System Loss	dB	- 46.7 dB

Waveguide	________ dB	3.0 dB
Connectors	________ dB	1.0 dB
Other *	________ dB	— db
Component Losses	dB	- 4.0 dB
Waveguide	________ dB	6.0 dB
Connectors	________ dB	1.0 dB
Other *	________ dB	— dB
Component Losses	dB	-7.0 dB
Transmitter Output Level	dBm	+25.0 dBm
Antenna System Loss	dB	- 46.7 dB

Algebraic sum of above values

Received Signal Level	dBm	-32.7 dBm

Threshold**	dBm	-75.0 dBm
Received Signal Level	dBm	-32.7 dBm
Fade Margin	dB	42.3 dB

* COMPONENT LOSSES

Component losses between the antenna feed and transmitter or receiver OTHER THAN WAVEGUIDE AND CONNECTORS, may be caused by circulators, hybrids, filters, switches, combiners or any other components that may be inserted between the transmitter or receiver terminals and the antenna feed.

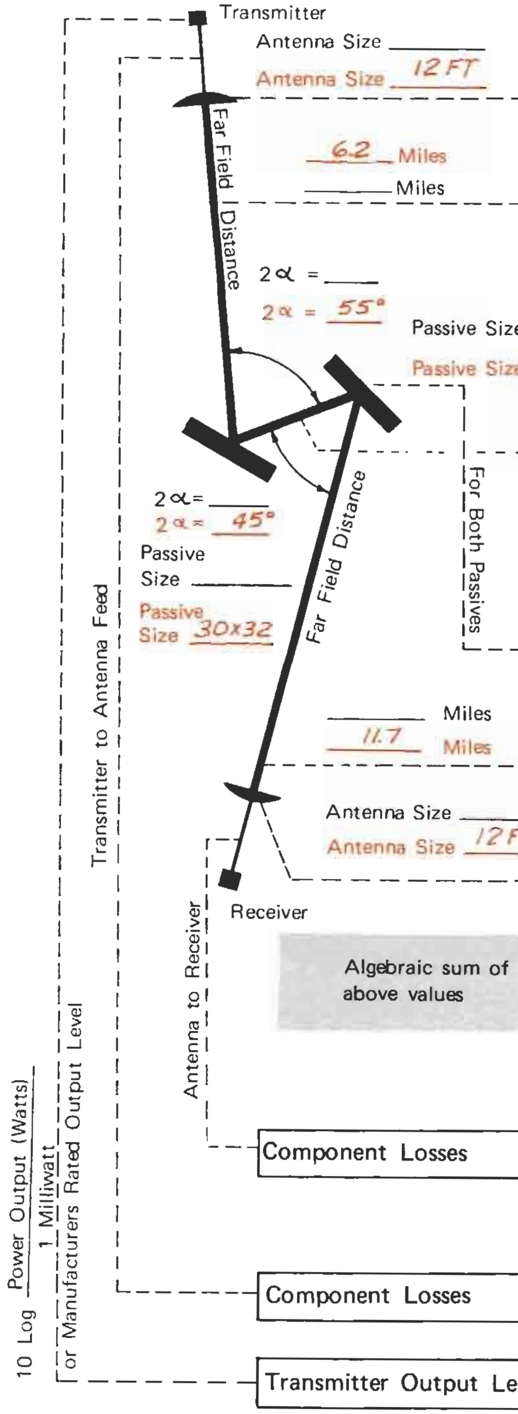
** THRESHOLD

A practical threshold for the receiver system is usually evaluated. This is often regarded as the FM Improvement Threshold or the point where baseband signal - to - noise is 30dB. It is the median threshold level provided by the system in the absence of fading.

DOUBLE PASSIVE REPEATERS, FAR FIELD OF BOTH ANTENNAS

Example of path calculation is shown in red.

Frequency GHz ___ 6.175 GHz



Antenna Size ______
Antenna Size 12 FT

Antenna Gain dB ___ +44.8 dB

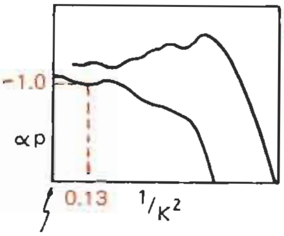
6.2 Miles
______ Miles

Free Space Loss dB ___ -128.3 dB

2α = ____
2α = 55°

Passive Size ______
Passive Size 30 x 32

______ Feet
340 Feet



$1/K^2 = \frac{(2)(0.9836/6.175)(340)}{(30)(32)(\cos 55/2)}$

$\frac{b}{a} = \sqrt{\frac{887}{852}} = 1.02$

See page 38

Where $1/K^2$ is less than 0.1 use −1.0 dB for close coupling loss.

Close Coupling Loss αp ______ dB ___ -1.0 dB

Far Field Gain of Passive Repeater With Smallest Effective Area .... ______ dB ___ +112.4 dB

Net Passive Repeater Gain dB ___ +111.4 dB

2α = ____
2α = 45°

Passive Size ______
Passive Size 30x32

______ Miles
11.7 Miles

Free Space Loss dB ___ -133.8 dB

Antenna Size ______
Antenna Size 12 FT.

Antenna Gain dB ___ +44.8 dB

Algebraic sum of above values

Antenna System Loss dB ___ -61.1 dB

Waveguide ______ dB ___ 3.0 dB
Connectors ______ dB ___ 0.5 dB
Other * ______ dB ___ – dB

Component Losses dB ___ -3.5 dB

Waveguide ______ dB ___ 2.0 dB
Connectors ______ dB ___ 0.5 dB
Other * ______ dB ___ – dB

Component Losses dB ___ -2.5 dB

Transmitter Output Level dBm ___ +30.0 dBm

Antenna System Loss dB ___ -61.1 dB

Algebraic sum of above values

Received Signal Level dBm ___ -37.1 dBm

Threshold ** dBm ___ -77.0 dBm

Received Signal Level dBm ___ -37.1 dBm

Fade Margin dB ___ 39.9 dB

* COMPONENT LOSSES

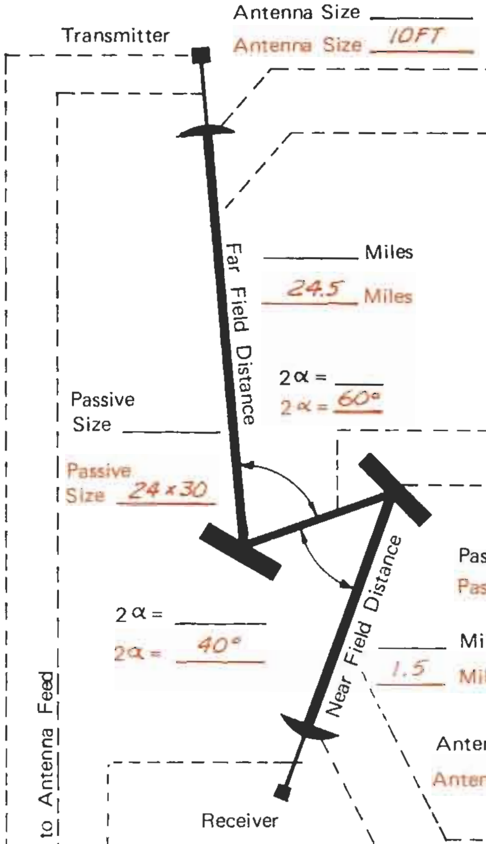
Component losses between the antenna feed and transmitter or receiver OTHER THAN WAVEGUIDE AND CONNECTORS, may be caused by circulators, hybrids, filters, switches, combiners or any other components that may be inserted between the transmitter or receiver terminals and the antenna feed.

** THRESHOLD

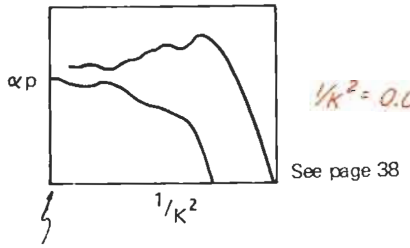
A practical threshold for the receiver system is usually evaluated. This is often regarded as the FM Improvement Threshold or the point where baseband signal - to - noise is 30 dB. It is the median threshold level provided by the system in the absence of fading.

DOUBLE PASSIVE REPEATERS, NEAR FIELD OF ONE ANTENNA

Example of path calculation is shown in red.



Frequency	GHz	6.175 GHz
Antenna Gain	dB	+43.2 dB
Free Space Loss	dB	−140.2 dB

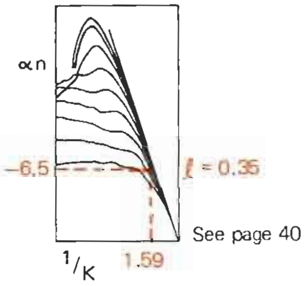


$1/K^2 = 0.03$

See page 38

Where $1/K^2$ is less than 0.1 use -1.0 dB for close coupling loss.

Close Coupling Loss, αp	dB	−1.0 dB



See page 40

Note: Use the smallest effective area of the two passives to determine αn, even though the passive with the largest effective area may be facing the closer antenna.

Near Field Loss or Gain, αn=(−)or(+)	dB	−6.5 dB
Antenna Gain	dB	+43.2 dB

Algebraic sum of above values

Antenna System Loss	dB	−61.3 dB

Antenna to Receiver

Wave guide	dB	2.0 dB
Connectors	dB	0.5 dB
Other *	dB	— dB
Component Losses	dB	−2.5 dB

Transmitter to Antenna Feed

Waveguide	dB	4.0 dB
Connectors	dB	0.5 dB
Other *	dB	— dB
Component Losses	dB	−4.5 dB

10 Log $\frac{\text{Power Output (Watts)}}{\text{1 Milliwatt}}$ or Manufacturers Rated Output Level

Transmitter Output Level	dBm	+30.0 dBm
Antenna System Loss	dB	−61.3 dB

Algebraic sum of above values

Received Signal Level	dBm	−38.3 dBm

Threshold **	dBm	−77.0 dBm
Received Signal Level	dBm	−38.3 dBm
Fade Margin	dB	38.7 dB

* COMPONENT LOSSES

Component losses between the antenna feed and transmitter or receiver OTHER THAN WAVEGUIDE AND CONNECTORS, may be caused by circulators, hybrids, filters, switches, combiners or any other components that may be inserted between the transmitter or receiver terminals and the antenna feed.

** THRESHOLD

A practical threshold for the receiver system is usually evaluated. This is often regarded as the FM Improvement Threshold or the point where baseband signal - to - noise is 30 dB. It is the median threshold level provided by the system in the absence of fading.

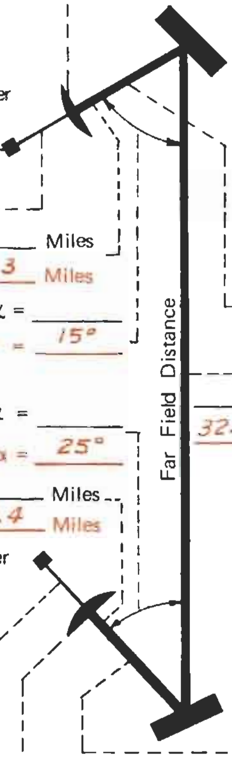
DOUBLE PASSIVE REPEATERS, NEAR FIELD OF BOTH ANTENNAS

Example of path calculation is shown in red.

Frequency GHz 8.075 GHz

Antenna Gain dB +41.1 dB

Transmitter

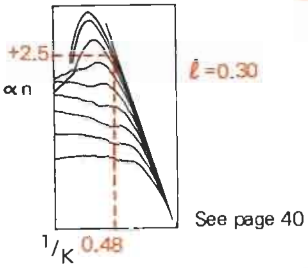


Passive Size ______

Passive Size 16×20

Antenna Size ______

Antenna Size 6FT.



______ Miles

0.3 Miles

2α = ______

2α = 15°

Near Field Loss or Gain, αn=(−)or(+) dB +2.5 dB

Free Space Loss dB −144.9 dB

Far Field Distance

______ Miles

32.0 Miles

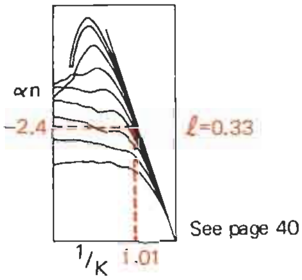
2α = ______

2α = 25°

______ Miles

1.4 Miles

Receiver



Antenna Size ______

Antenna Size 10FT

Passive Size ______

Passive Size 24×30

Near Field Loss or Gain, αn=(−)or(+) dB −2.4 dB

Antenna Gain dB +45.6 dB

Algebraic sum of above values

Antenna System Loss dB −58.1 dB

Transmitter to Antenna Feed

Antenna to Receiver

10 Log Power Output (Watts) / 1 Milliwatt or Manufacturers Rated Output Level

Waveguide ______ dB 4.2 dB
Connectors ______ dB 0.8 dB
Other * ______ dB — dB

Component Losses dB −5.0 dB

Waveguide ______ dB 3.2 dB
Connectors ______ dB 0.8 dB
Other * ______ dB — dB

Component Losses dB −4.0 dB

Transmitter Output Level dBm +37.0 dBm

Antenna System Loss dB −58.1 dB

Algebraic sum of above values

Received Signal Level dBm −30.1 dBm

Threshold ** dBm −71.0 dBm

Received Signal Level dBm −30.1 dBm

Fade Margin dB 40.9 dB

* COMPONENT LOSSES

Component losses between the antenna feed and transmitter or receiver OTHER THAN WAVEGUIDE AND CONNECTORS, may be caused by circulators, hybrids, filters, switches, combiners or any other components that may be inserted between the transmitter or receiver terminals and the antenna feed.

** THRESHOLD

A practical threshold for the receiver system is usually evaluated. This is often regarded as the FM Improvement Threshold or the point where baseband signal - to - noise is 30 dB. It is the median threshold level provided by the system in the absence of fading.

ADDITIONAL EXAMPLES OF MICROWAVE PATH CONFIGURATIONS USING PASSIVE REPEATERS

The five system configurations shown to the right, although somewhat unusual, are practical arrangements and can be evaluated and used with confidence. Examples and work sheets are not provided for these specific configurations, but the methods demonstrated in the preceding examples may be extended to cover these situations. Obviously, other arrangements may be selected to suit the particular terrain available between two stations and provide a radio path meeting system requirements.

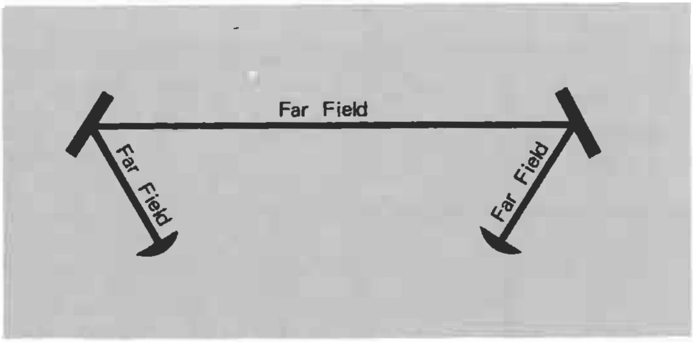
A system configuration not shown is one with both antennas in the near field with respect to a single passive repeater. This is not a practical situation since the size of the passive and perhaps the antennas, would be reduced until at least one path would be far field.

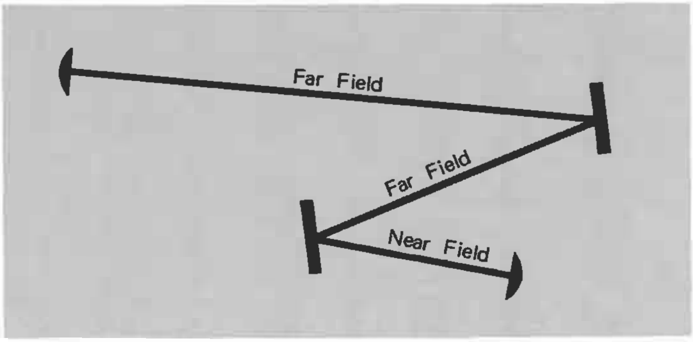
Occasionally, a path with an antenna and passive in the near field, coupled with a second passive in the near field,with the first passive must be evaluated (two passives not coupled close enough to be in the range of graph on page 38). The solution is beyond the scope of this chapter but the reader is encouraged to work with the Microflect Engineering Department to solve any problem of this type.

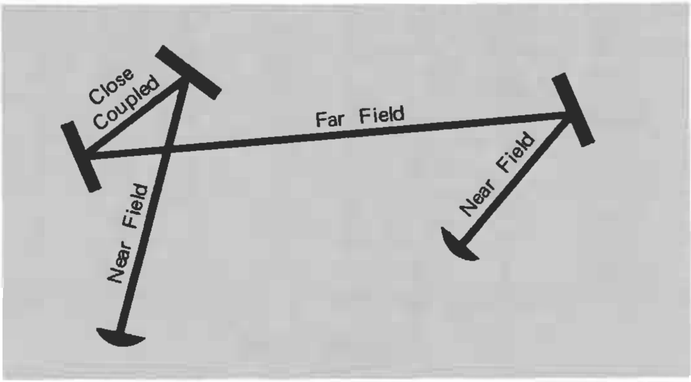
It is necessary to try several combinations of antenna and passive repeater sizes, in all situations involving passive repeaters, until the optimum arrangement is found. In a particular instance it may be that the passive repeater site is limited in size and/or accessibility; in which case a smaller passive, larger antennas or greater transmitter power may be used; or it may be that one or both antennas must be mounted on tall self-supporting towers which would dictate the use of a larger passive with smaller antennas, thus reducing the tower cost.

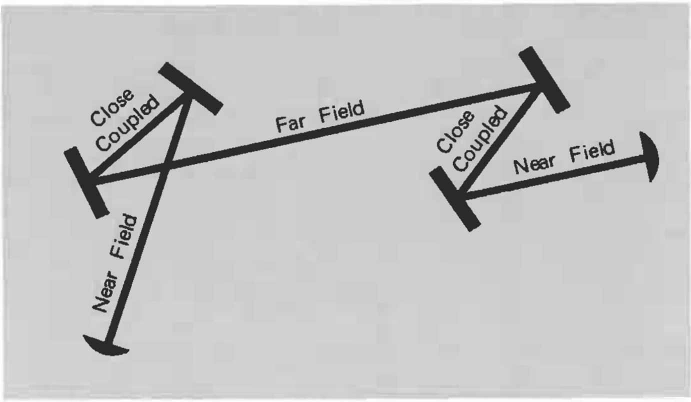
In any case, it should be the aim of the system designer to reduce the installed cost (and annual maintenance cost) of a system without sacrificing overall performance. To optimize a system layout it is necessary to consider site availability, station appearance in sensitive areas, cost and practicality of roads and power lines, cost of maintenance and hazards involved with repair and regular maintenance.

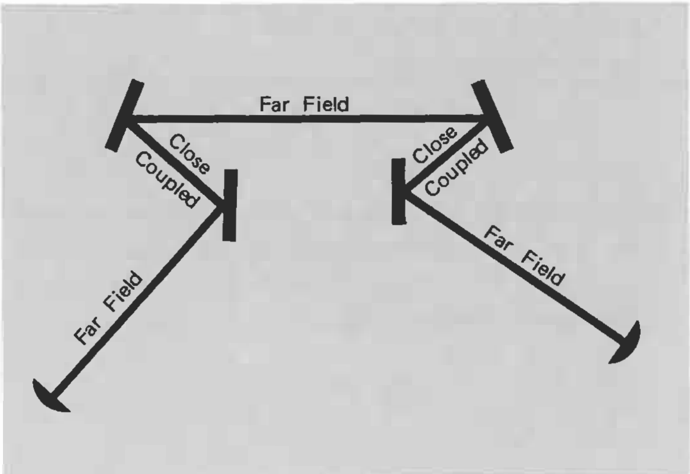
Microflect 16x20 Passive Repeater











ANTENNA GAIN

FREQUENCY GHz	THEORETICAL GAIN AT 55% EFFICIENCY FOR PLANE POLARIZED PARABOLIC ANTENNAS DIAMETER IN FEET: 20 Log F_{GHz} + 20Log D + 7.5 DIAMETER IN METERS: 20 Log F_{GHz} + 20 Log D + 17.8							
	ANTENNA DIAMETER (FEET)							
	2	4	6	8	10	12	15	16
1.780	—	24.5	28.0	30.5	32.4	34.0	36.0	36.5
2.000	—	25.5	29.0	31.5	33.5	35.0	37.0	37.5
2.140	—	26.1	29.6	32.1	34.0	35.6	37.6	38.1
2.595	—	27.8	31.3	33.8	35.7	37.3	39.2	39.8
3.950	25.4	31.4	34.9	37.4	39.4	41.0	42.9	43.5
4.700	26.9	32.9	36.5	39.0	40.9	42.5	44.4	45.0
6.175	29.3	35.3	38.8	41.3	43.2	44.8	46.8	47.3
6.725	30.0	36.0	39.6	42.1	44.0	45.6	47.5	48.1
7.000	30.4	36.4	39.9	42.4	44.4	45.9	47.9	48.4
7.435	30.9	36.9	40.4	42.9	44.9	46.4	48.4	49.0
8.075	31.6	37.6	41.1	43.7	45.6	47.2	49.1	49.7
11.200	34.5	40.5	44.0	46.5	48.4	50.0	52.0	52.5
12.450	35.4	41.4	44.9	47.4	49.4	51.0	52.9	53.5
12.825	35.6	41.6	45.2	47.7	49.6	51.2	53.1	53.7
13.075	35.8	41.8	45.3	47.8	49.7	51.3	53.3	53.8
14.825	36.9	42.9	46.4	48.9	50.9	52.4	54.4	54.9

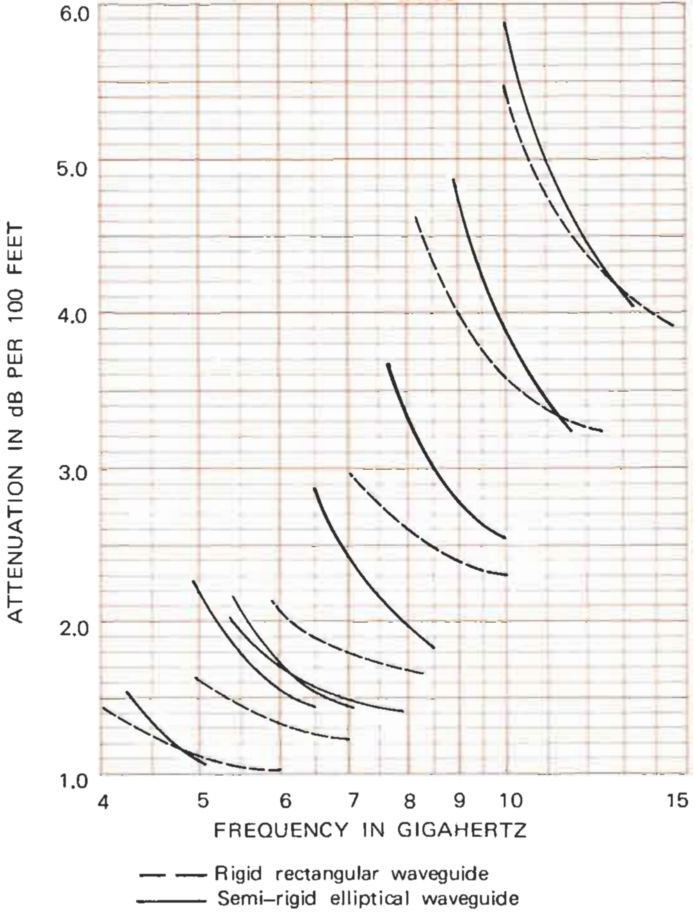
Theoretical Incremental Gain(dB) 6.02 3.52 2.50 1.94 1.58 1.94 0.56

RADOME LOSS

PARABOLIC ANTENNA DIAMETER (FEET)	FREQUENCY (GHz)			
	2.0	4.0	6.0	11.0
4	0.1	0.2	0.4	1.3
6	0.1	0.3	0.5	1.3
8	0.1	0.3	0.5	1.4
10	0.1	0.4	0.8	1.9
12	0.1	0.4	0.9	1.9

Typically 0.1 dB radome loss for shrouded antennas with hypalon covers.

WAVEGUIDE LOSS



The values shown for antenna gains and radome and waveguide losses are typical values and are listed here as a convenience only. Final path calculations should reflect actual manufacturers' published values.

FREE SPACE LOSS BETWEEN ISOTROPIC RADIATORS

The chart below may be used to determine the free space loss, for the frequencies listed, with the distance expressed in miles or kilometers. The free space loss, for distances not charted, may be interpolated or calculated.

FREQUENCY (GHz) Center of band	20 Log F GHz
1.780	5.01
1.920	5.67
2.000	6.02
2.120	6.53
2.140	6.61
2.170	6.73
2.190	6.81
2.595	8.28
3.950	11.93
4.700	13.44
6.175	15.81
6.725	16.55
7.000	16.90
7.435	17.43
8.075	18.14
11.200	20.98
12.450	21.90
12.825	22.16
13.075	22.33
14.825	23.42

d	20 Log d	d	20 Log d	d	20 Log d	d	20 Log d	d	20 Log d	d	20 Log d	d	20 Log d	d	20 Log d
1.0	0.00	3.2	10.10	5.4	14.65	7.6	17.62	11.6	21.29	16.0	24.08	26.0	28.30	56.0	34.96
1.1	0.83	3.3	10.37	5.5	14.81	7.7	17.73	11.8	21.44	16.2	24.19	27.0	28.63	58.0	35.27
1.2	1.58	3.4	10.63	5.6	14.96	7.8	17.84	12.0	21.58	16.4	24.30	28.0	28.94	60.0	35.56
1.3	2.28	3.5	10.88	5.7	15.12	7.9	17.95	12.2	21.73	16.6	24.40	29.0	29.25	62.0	35.85
1.4	2.92	3.6	11.13	5.8	15.27	8.0	18.06	12.4	21.87	16.8	24.51	30.0	29.54	64.0	36.12
1.5	3.52	3.7	11.36	5.9	15.42	8.2	18.28	12.6	22.01	17.0	24.61	31.0	29.83	66.0	36.39
1.6	4.08	3.8	11.60	6.0	15.56	8.4	18.49	12.8	22.14	17.5	24.86	32.0	30.10	68.0	36.65
1.7	4.61	3.9	11.82	6.1	15.71	8.6	18.69	13.0	22.28	18.0	25.11	33.0	30.37	70.0	36.90
1.8	5.11	4.0	12.04	6.2	15.85	8.8	18.89	13.2	22.41	18.5	25.34	34.0	30.63	72.0	37.15
1.9	5.58	4.1	12.26	6.3	15.99	9.0	19.08	13.4	22.54	19.0	25.58	35.0	30.88	74.0	37.39
2.0	6.02	4.2	12.46	6.4	16.12	9.2	19.28	13.6	22.67	19.5	25.80	36.0	31.13	76.0	37.62
2.1	6.44	4.3	12.67	6.5	16.26	9.4	19.46	13.8	22.80	20.0	26.02	37.0	31.36	78.0	37.84
2.2	6.85	4.4	12.87	6.6	16.39	9.6	19.65	14.0	22.92	20.5	26.24	38.0	31.60	80.0	38.06
2.3	7.23	4.5	13.06	6.7	16.52	9.8	19.82	14.2	23.05	21.0	26.44	39.0	31.82	85.0	38.59
2.4	7.60	4.6	13.26	6.8	16.65	10.0	20.00	14.4	23.17	21.5	26.65	40.0	32.04	90.0	39.08
2.5	7.96	4.7	13.44	6.9	16.78	10.2	20.17	14.6	23.29	22.0	26.85	42.0	32.46	95.0	39.55
2.6	8.30	4.8	13.62	7.0	16.90	10.4	20.34	14.8	23.41	22.5	27.04	44.0	32.87	100.0	40.00
2.7	8.63	4.9	13.80	7.1	17.03	10.6	20.51	15.0	23.52	23.0	27.23	46.0	33.26	105.0	40.42
2.8	8.94	5.0	13.98	7.2	17.15	10.8	20.67	15.2	23.64	23.5	27.42	48.0	33.63	110.0	40.83
2.9	9.25	5.1	14.15	7.3	17.27	11.0	20.83	15.4	23.75	24.0	27.61	50.0	33.98	115.0	41.21
3.0	9.54	5.2	14.32	7.4	17.38	11.2	20.98	15.6	23.86	24.5	27.78	52.0	34.32	120.0	41.58
3.1	9.83	5.3	14.49	7.5	17.50	11.4	21.14	15.8	23.97	25.0	27.96	54.0	34.65	125.0	41.94

WHEN DISTANCE IS IN MILES:

Free space loss $= 96.6 + 20 \text{ Log } F_{GHz} + 20 \text{ Log } d$ *Miles*

Example: $F = 7.435$ *GHz,* $d = 22.5$ *Miles*
Path loss $= 96.6 + 17.43 + 27.04 = 141.07$ *dB*

WHEN DISTANCE IS IN KILOMETERS:

Free space loss $= 92.4 + 20 \text{ Log } F_{GHz} + 20 \text{ Log } d$ *Kilometers*

Example: $F = 11.2$ *GHz,* $d = 10.50$ *Kilometers*
Path loss $= 92.4 + 20.98 + 20.43 = 133.81$ *dB*

PASSIVE REPEATER GAIN, dB
FOR $\alpha = 0$ @ 100% EFFICIENCY (Except for shaded areas B,C,and D)

(Sizes: Height in Feet X Width in Feet / Dimensions in Meters)

FREQ, (GHz) Center of Band	*8x10* *2.43x3.04*	*8x12* *2.43x3.65*	*10x16* *3.04 x 4.87*	*12x16* *3.65 x 4.87*	*14x16* *4.26 x 4.87*	*16x20* *4.87 x 6.09*	*16x24* *4.87 x 7.31*	*20x 24* *6.09 x 7.31*	*20x32* *6.09 x 9.75*	*24x30* *7.31 x 9.14*	*30x32* *9.14 x 9.75*	*30x40* *9.14 x 12.19*	*30x48* *9.14 x 14.63*	*40x50* *12.19 x 15.24*	*40x60* *12.19 x 18.29*
Incremental Gain (dB) →		1.58	4.44	1.58	1.34	3.10	1.58	1.94	2.50	1.02	2.50	1.94	1.58	2.85	1.58
1.780	70.35	71.93	76.37	77.95	79.29	82.39	83.97	85.91	88.41	89.43	91.93	93.87	95.45	98.30	99.88
1.920	71.66	73.24	77.68	79.26	80.60	83.70	85.28	87.22	89.72	90.74	93.24	95.18	96.76	99.61	101.19
2.000	72.37	73.95	78.39	79.97	81.31	84.41	85.99	87.93	90.43	91.45	93.95	95.89	97.47	100.32	101.90
2.120	73.38	74.96	79.40	80.98	82.32	85.42	87.00	88.94	91.44	92.46	94.96	96.90	98.48	101.33	102.91
2.140	73.54	75.12	79.56	81.14	82.48	85.58	87.16	89.10	91.60	92.62	95.12	97.06	98.64	101.49	103.07
2.170	73.79	75.37	79.81	81.39	82.73	85.83	87.41	89.35	91.85	92.87	95.37	97.31	98.89	101.74	103.32
2.190	73.95	75.53	79.97	81.55	82.89	85.99	87.57	89.51	92.01	93.03	95.53	97.47	99.05	101.90	103.48
2.595	76.89	78.47	82.91	84.49	85.83	88.93	90.51	92.45	94.95	95.97	98.47	100.41	101.99	104.84	106.42
3.950	84.19	85.77	90.21	91.79	93.13	96.23	97.81	99.75	102.25	103.27	105.77	107.71	109.29	112.14	113.72
4.700	87.21	88.79	93.23	94.81	96.15	99.25	100.83	102.77	105.27	106.29	108.79	110.73	112.31	115.16	116.74
6.175	91.95	93.53	97.97	99.55	100.89	103.99	105.57	107.51	110.01	111.03	113.53	115.47	117.05	118.90	120.48
6.725	93.44	95.02	99.46	101.04	102.38	105.48	107.06	109.00	111.50	112.52	115.02	116.96	118.54	120.39	121.97
7.000	94.13	95.71	100.15	101.73	103.07	106.17	107.75	109.69	112.19	113.21	115.71	117.65	119.23	121.08	122.66
7.435	95.18	96.76	101.20	102.78	104.12	107.22	108.80	110.74	113.24	114.26	116.76	118.70	119.28	122.13	122.71
8.075	96.61	98.19	102.63	104.21	105.55	108.65	110.23	112.17	114.67	115.69	118.19	119.13	120.71	122.56	124.14
11.200	102.30	103.88	108.32	109.90	111.24	114.34	115.92	117.86	119.36	120.38	122.88	123.82	125.40	127.25	128.83
12.450	104.14	105.72	110.16	111.74	113.08	116.18	117.76	119.70	121.20	122.22	123.72	125.66	127.24		
12.825	104.65	106.23	110.67	112.25	113.59	116.69	118.27	119.21	121.71	122.73	124.23	126.17	127.75		
13.075	104.99	106.57	111.01	112.59	113.93	117.03	118.61	119.55	122.05	123.07	124.57	126.51			
14.825	107.17	108.75	113.19	114.77	116.11	119.21	119.79	121.73	123.23	124.25	126.75				

(1) Use the values shown above in conjunction with the correction factors shown on page 36.

(2) Values shown above are calculated from the relationship:

$$\text{Passive Repeater Gain} = 20 \text{ Log } \frac{4\pi\,(\text{Area})\,(\cos\alpha)}{\lambda^2}$$

NOTE: Use loss factors of -1dB, -2dB, and -3dB for large passives used at higher micro-wave frequencies in computations using the graph for "near field losses and gains". These losses are not shown for the examples on pages 28, 30, & 31.

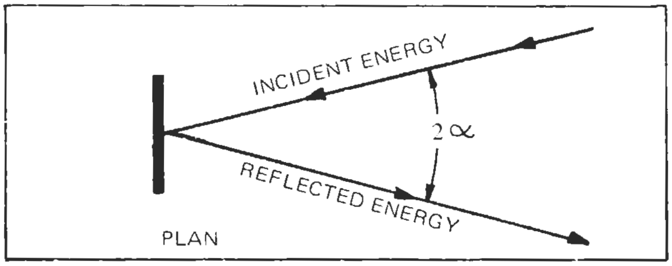
A (3) Zone A is a combination of small passive repeaters and low frequencies where the effects of surrounding terrain and large objects in the vicinity of the passive, may produce echoes (intermodulation noise) and thus degrade system performance. The selection of this area is arbitrary and is presented to alert the user to the necessity for a careful site evaluation before selecting a passive repeater from within this range.

B
C
D
(4) Zones B,C, and D contain gain figures reduced by 1,2, and 3 db respectively from those calculated in (2) above. These reductions are arbitrary and are an attempt to reflect the reduced efficiencies expected when very large passive repeaters are used in systems operating at the higher microwave frequencies.

(5) For all passive repeater applications above 12GHz, special face flatness requirements must be met. Consult Microflect Co. when planning such an installation.

GAIN REDUCTION FACTOR FOR VALUES OF α (OR C/2*)

α Degrees	20 Log cos α	α	20 Log cos α	α	20 Log cos α	α	20 Log cos α
6	0.05	21	0.60	36	1.84	51	4.02
7	0.07	22	0.66	37	1.95	52	4.21
8	0.09	23	0.72	38	2.07	53	4.41
9	0.11	24	0.79	39	2.19	54	4.62
10	0.13	25	0.85	40	2.31	55	4.83
11	0.16	26	0.93	41	2.44	56	5.05
12	0.20	27	1.00	42	2.58	57	5.28
13	0.23	28	1.08	43	2.72	58	5.52
14	0.26	29	1.16	44	2.86	59	5.76
15	0.30	30	1.25	45	3.01	60	6.02
16	0.34	31	1.34	46	3.16	61	6.29
17	0.39	32	1.43	47	3.32	62	6.57
18	0.44	33	1.53	48	3.49	63	6.86
19	0.49	34	1.63	49	3.66	64	7.16
20	0.54	35	1.73	50	3.84	65	7.48



The values shown on this chart are subtracted directly from those given on page 35 to account for the change in effective areas of the passive with changing values of α .

From the example on page 27: Frequency = 6.725 GHz

Passive Size = 30 x 40 feet

$2\alpha = 110^\circ$, $\alpha = 55^\circ$

From page 35 .... 116.96 dB

From chart above .... -4.83 dB

Passive gain .... 112.13 dB

*NOTES ON EFFECTIVE AREA The use of the above chart is based on the assumption that the effective area of a passive repeater is: $A_e \cong (\text{Area})\ (\cos\alpha)$ where the "Area" is the nominal height times the width of the passive, and "α" is half the horizontal included angle between paths. However, the true effective area is: $A_e = (\text{Area})(\cos C/2)$ where C is the true angle between the beam paths. Note: Calculating the true effective area is advisable when one or both beam paths are in excess of 20° from horizontal.

The angle C may be evaluated from the following relationships:

$$\cos C/2 = \frac{\sin\theta_1 + \sin\theta_2}{2\sin\theta_3}$$

where: θ_1 is the least vertical path angle

θ_2 is the greatest vertical path angle

θ_3 is the vertical face angle of the passive.

θ_1 and θ_2 may be measured or may be calculated from the site elevations and path lengths, and θ_3 is calculated from the following:

$$\tan\Delta\alpha = \frac{(\tan\alpha)\ (\cos\theta_1 - \cos\theta_2)}{(\cos\theta_1 + \cos\theta_2)}, \text{ and}$$

$$\tan\theta_3 = \frac{(\cos\Delta\alpha)\ (\sin\theta_1 + \sin\theta_2)}{(\cos\alpha)\ (\cos\theta_1 + \cos\theta_2)}$$

Sign convention: all cosines positive. Sines are positive when the angle from the passive is below the horizontal and negative when above. When the true effective area is calculated, substitute C/2 for α in the above chart and proceed as before.

EXPLANATION AND DERIVATION OF PASSIVE REPEATER GAIN

Because of the connotation often placed on the term, "gain" one must return to definition in order to understand gain of a passive repeater where the device is completely passive with no external energy injected into the system at that point.

The following definition was developed by an E.I.A. subcommittee for revision of E.I.A. standard RS-195-A.

"DEFINITION FOR MIRROR - TYPE: The one - way gain of a mirror - type passive repeater, defined as a function of frequency, is the ratio of the power density at a distant point due to the passive repeater to the power density which would exist at the same point if the passive repeater were replaced by a matched, isotropic antenna of 100 per cent ohmic efficiency located at the center of the reflecting face of the passive repeater and fed with RF power equal to that accepted by the passive repeater. Unless otherwise stated the gain shall imply the maximum (on-axis) gain.

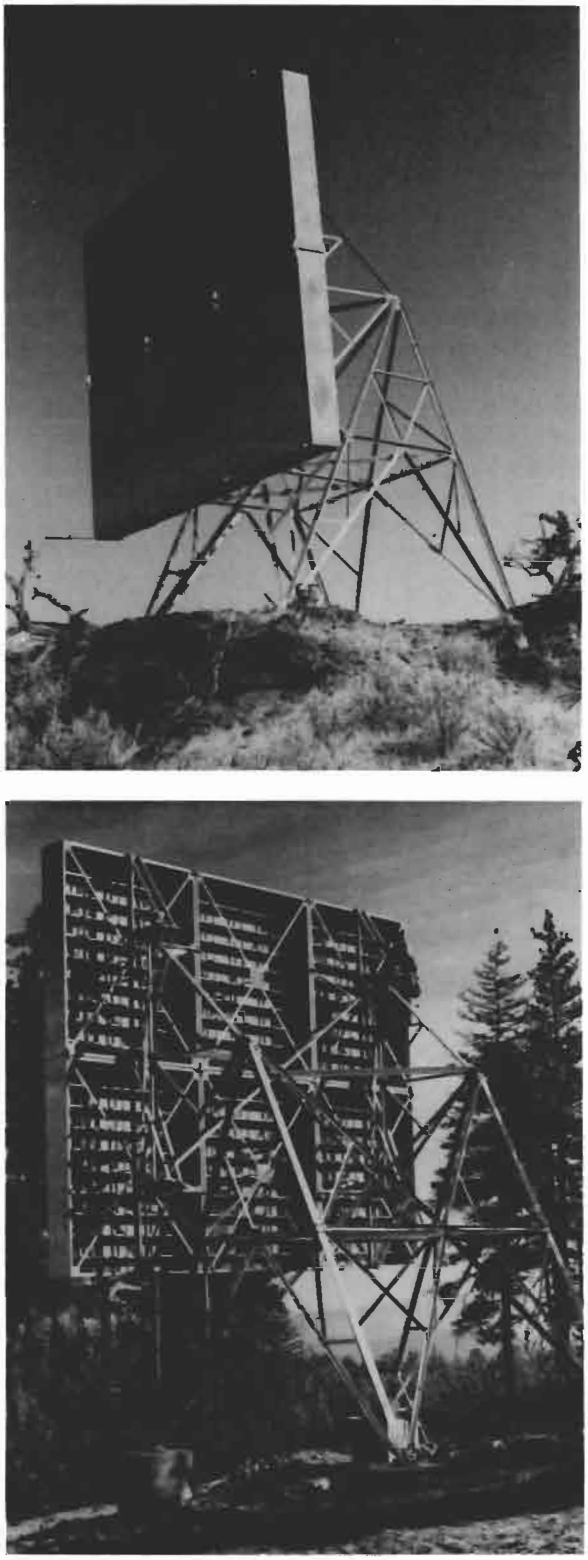
Notes:
(1) The gain is usually expressed in decibels relative to isotropic. (dBi).
(2) The gain is usually expressed as the "two - way" gain to account for the part which pertains to the incoming energy and that which pertains to the reflected beam.
(3) When the mirror (reflector) is in the Fresnel Region of a direct radiator, the gain is usually expressed as a correction factor in dB to the far - field gain of the direct radiator."

The key relationships are that of gain related to directivity and the reference devices, the isotropic receiver and radiator. Thus gains for passive repeaters are determined from directivity and the efficiency with isotropic devices as the basic reference.

The efficiencies involved are the polarization efficiency and the aperture efficiency. The polarization efficiency is usually considered 100% on microwave systems where an effort is made to match polarizations by adjustments of antenna feeds. * The aperture efficiency is taken as the ratio of the gain, G, to the dimension-less ratio, $4\pi A/\lambda^2$, where A is the area of the projection of the microwave aperture on the normal to the beam axis. For most passive repeaters the efficiency is taken as 100%** and "A" becomes Ae, the effective area. For flat - face reflectors the effective area, Ae, is then coincident with the geometric area taken as the projection of the reflector face normal to the beam axis. The far - field gain is then determined by the following:

$$\text{PASSIVE REPEATER GAIN (dBi)} = 20 \text{ Log} \frac{4\pi Ae}{\lambda^2}$$

λ = wavelength, Ae = effective area*



Front and back views of a 20 x 24 passive repeater.

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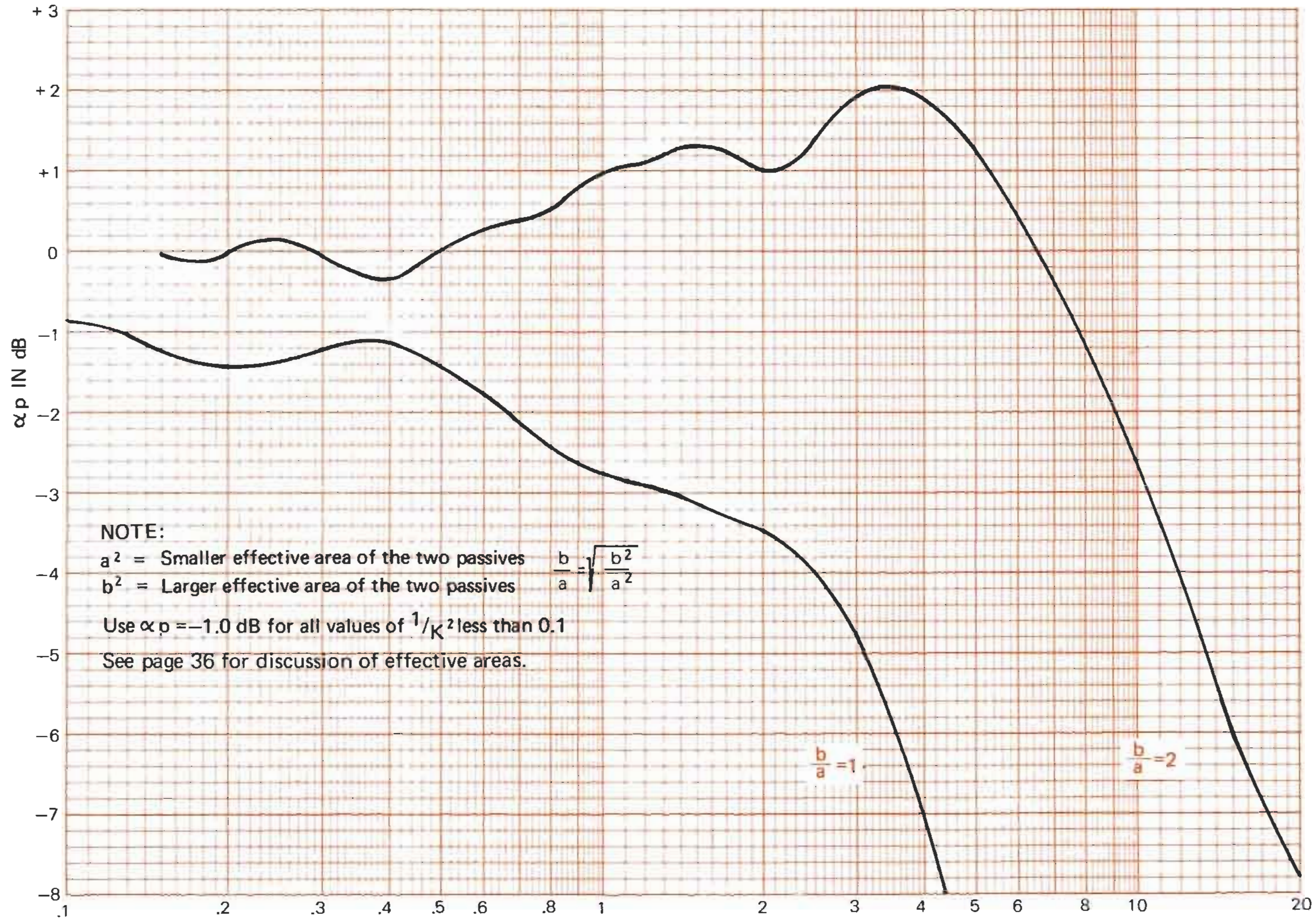
*See chapter VII -- Polarization Shift and Effective Area

** See note 4 on page 35 for some nominal efficiency reductions

DOUBLE PASSIVE REPEATER CLOSE COUPLING LOSS



NOTE:

a^2 = Smaller effective area of the two passives

b^2 = Larger effective area of the two passives

$\frac{b}{a}=\sqrt{\frac{b^2}{a^2}}$

Use $\alpha p = -1.0$ dB for all values of $1/K^2$ less than 0.1

See page 36 for discussion of effective areas.

$$1/K^2 = \frac{2\lambda d}{a^2}$$

NOTE: Use loss factors of -1dB, --2dB, and -3dB for large passives used at higher micro-wave frequencies in computations using the graph for "near field losses and gains". These losses are not shown for the examples on pages 28, 30 & 31. (See page 35)

DOUBLE PASSIVE ORIENTATION

Double passive repeaters are normally used, in place of a single passive repeater, when the transfer angle, ψ, is less than 50°. A clearance of about fifteen wavelengths should be provided between the incoming path and the adjacent passive, See figure 2-1.

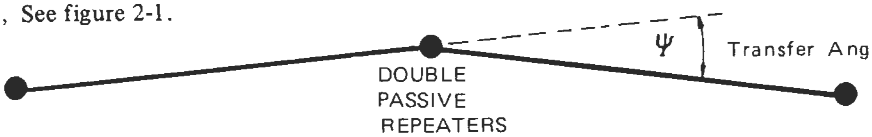
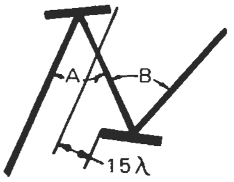


FIG. 2-1



Use when $\psi < 30^{\circ}$

$\psi = B - A$

FIG. 2-2

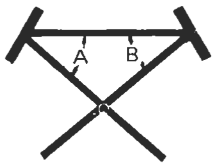
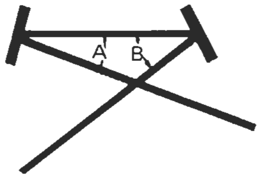


FIG. 2-3



Use 2-2 and 2-3 when $\psi > 30^{\circ}$

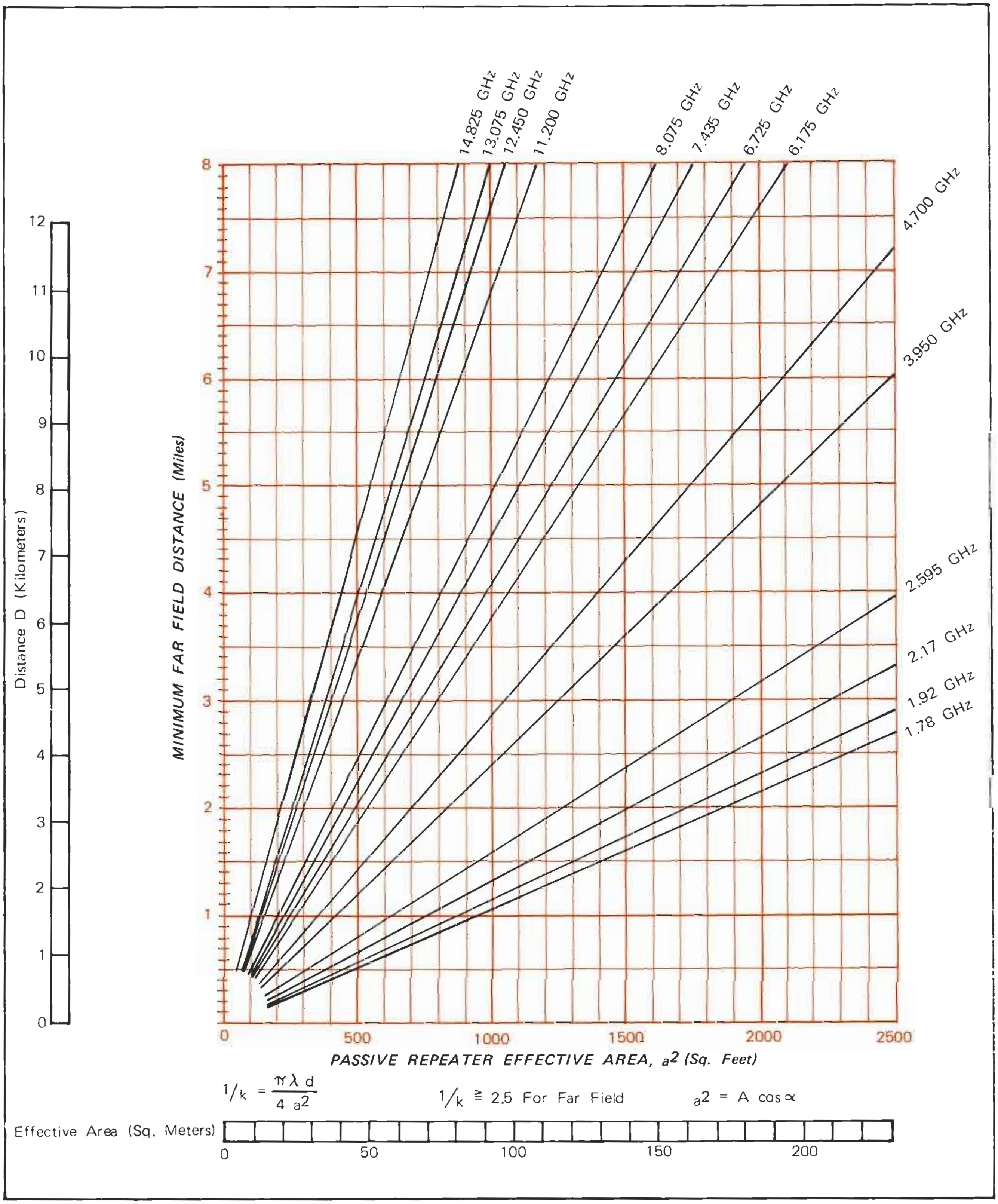
When site conditions permit, make A=B

$A=B=\frac{\psi}{2}$

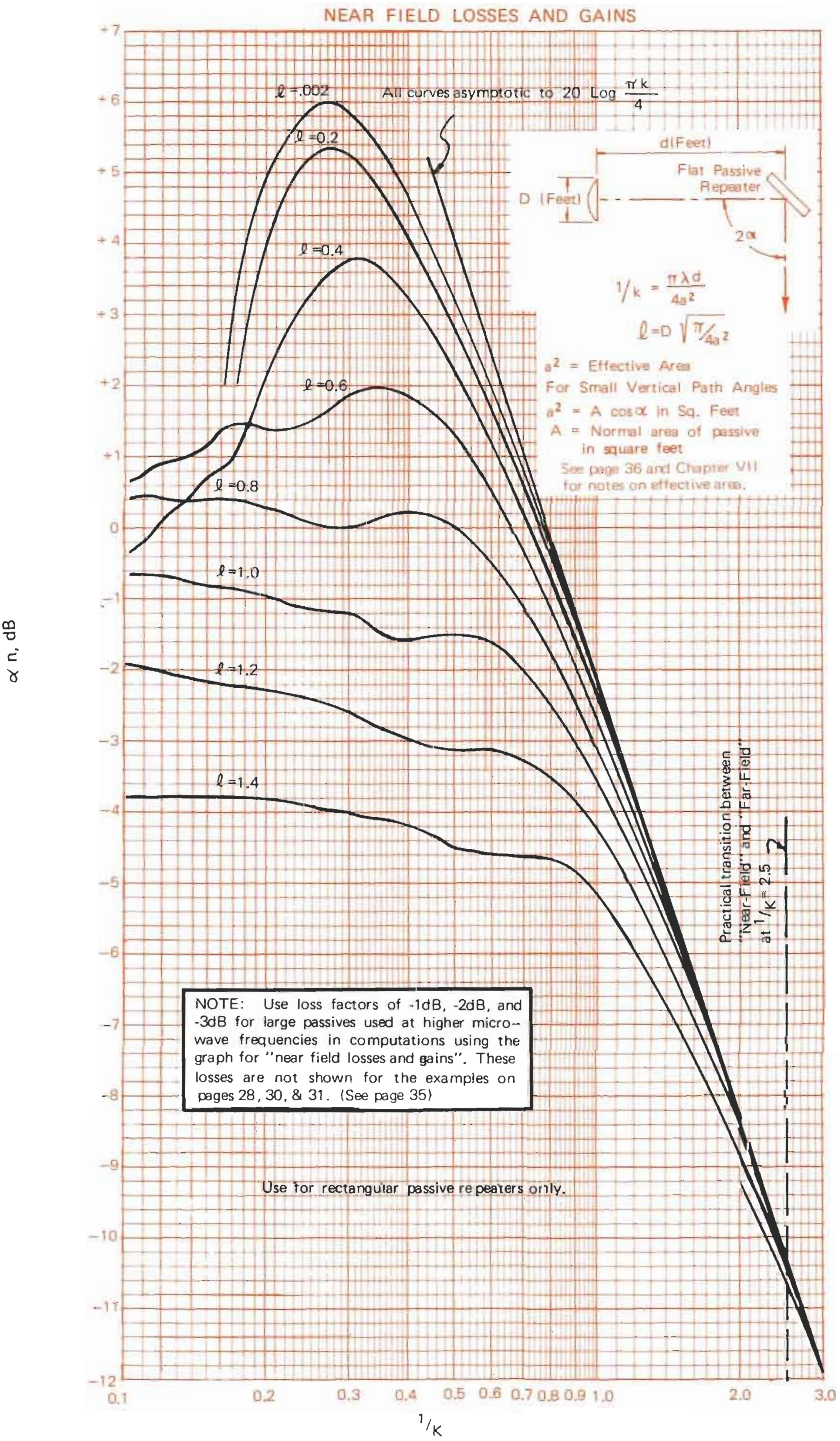
When A is unequal to B,

$A+B=\psi$

MINIMUM FAR FIELD DISTANCE



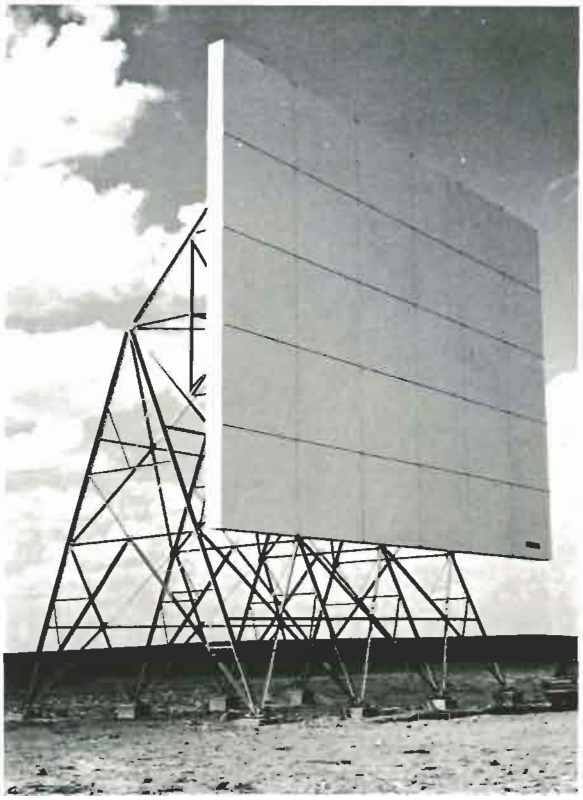
The graph shown above is used to quickly determine whether or not a passive is in the near field with respect to the adjacent antenna. If it appears that a near field situation may exist, calculate the value of 1/K (see page 40). If it is less than 2.5, use the graph on page 40 to determine "αn". The algebraic sum of the antenna gain and "αn" represents the net gain of the antenna, the near field path, and the passive repeater.



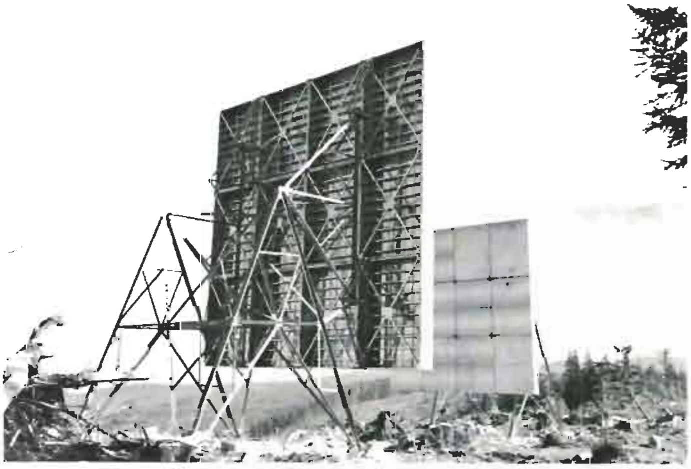
NEAR FIELD LOSSES AND GAINS

NOTE: Use loss factors of -1dB, -2dB, and -3dB for large passives used at higher micro-wave frequencies in computations using the graph for "near field losses and gains". These losses are not shown for the examples on pages 28, 30, & 31. (See page 35)

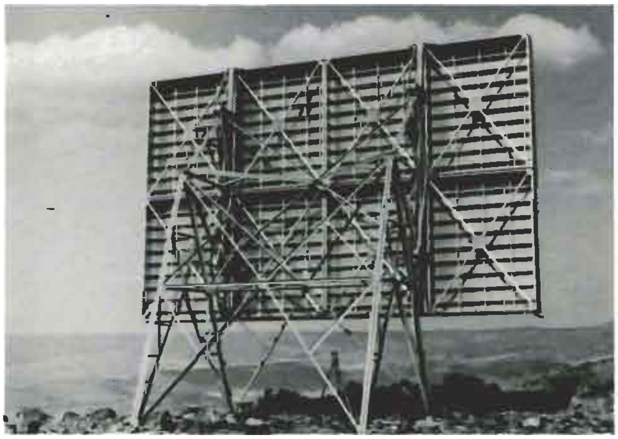
Use for rectangular passive repeaters only.



Microflect 40x60 Passive Repeater



Microflect Double 30x32 Passive Repeaters



20x32 Passive Repeater

CONVERSION FACTORS FOR METRIC UNITS

1 METER = 3.2808 FEET

1 KILOMETER = 0.6214 STATUTE MILE

1 FOOT = 0.3048 METERS

1 STATUTE MILE = 1.6094 KILOMETERS

DETERMINATION OF WAVELENGTH, λ

FEET $\lambda = 0.9836/F_{GHz}$

CENTIMETERS $\lambda = 30/F_{GHz}$

POWER LEVEL CONVERSIONS

WATTS	*dBm*
0.05	+17.0
0.10	+20.0
0.50	+27.0
0.70	+28.5
1.00	+30.0
2.00	+33.0
3.15	+35.0
4.00	+36.0
5.00	+37.0
8.00	+39.0
10.00	+40.0

NOTES ON CALCULATED RECEIVED SIGNAL LEVELS

The performance requirements of the system, such as the noise objectives, will generally dictate the signal levels to the receiver. However, the calculated received signal levels typically may be acceptable at the following levels.

NO. OF CHANNELS IN SYSTEM	*MINIMUM INPUT LEVEL*
300	−40 dBm
600	−37 dBm
960	−33 dBm
1200	−28 dBm

The table below lists the minimum input levels (measured in the absence of fading) for the C.C.I.R. international reference circuit.

NO. OF CHANNELS IN SYSTEM	*MINIMUM INPUT LEVEL*
60	−52 dBm
120	−46 dBm
300	−39 dBm
600	−33 dBm
960	−29 dBm
1800	−23 dBm

TYPICAL PRACTICAL THRESHOLD LEVELS FOR MICROWAVE RECEIVERS

NO. OF CHANNELS IN SYSTEM	*6 GHz*	*11 GHz*
300	−84 dBm	−83 dBm
600	−81 dBm	−80 dBm
960	−77 dBm	−76 dBm
1200	−71 dBm	−70 dBm
1800	−69 dBm	−67 dBm
VIDEO	−75 dBm	−74 dBm

COMMENTARY ON CHAPTER II

The following questions, answers and precautionary statements are appropriate for the correct application of the information in this chapter.

Questions often arise regarding the required accuracy of the horizontal included angle and the vertical angles of the microwave paths as viewed from the passive repeater. The accuracy of angles required for engineering and installing a passive depend upon the stage of the project. For instance, the passive repeater size can be selected from map information but footing locations for the passive must be obtained by surveying methods with appropriate consideration given to the adjustment range of the passive. As the project progresses it is desireable to make an accurate setting of the passive repeater face using conventional surveying methods.

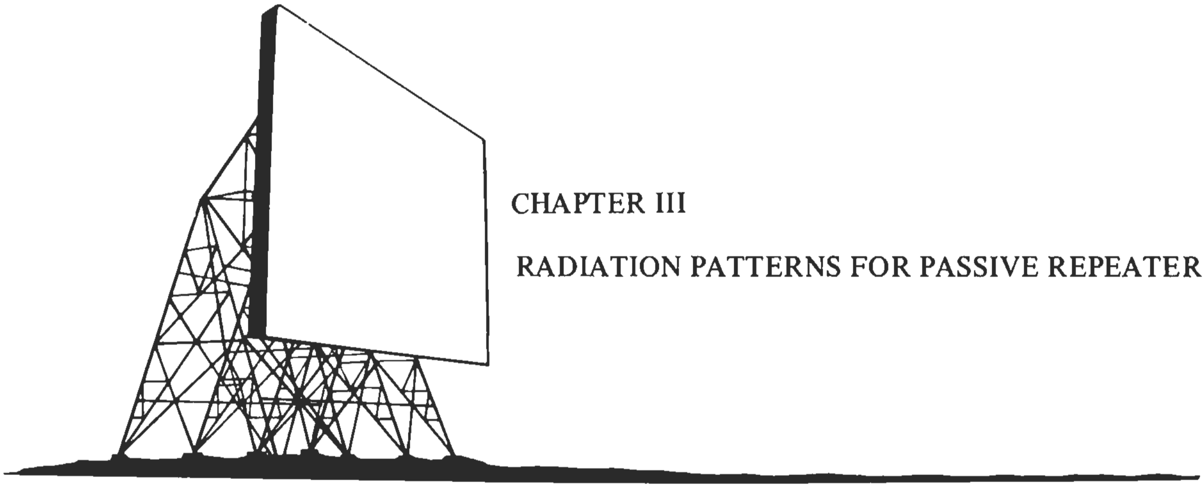
When the passive repeater effective area and gain is determined by the horizontal included angle, 2α, it is appropriate to question when the true angle between beam paths, C, should be used to determine the effective area and gain. If the vertical path angles are small, 10° to 15°, there is little difference in the gain values using "2α" or "C". However, when the vertical angles are large the effective area should be computed by using the true angle, C. When there is any doubt about significant gain differences by using "2α" or "C" in the computations, and where polarization shift may be a concern, the computations should be made using the true angle between beam paths. (See Chapter VII).

Most passive repeater applications allow the use of the horizontal angle, 2α, to determine gain. When the values of gain on page 35 are used care should be taken to include the gain reduction factors on page 36 and when appropriate the efficiency reductions indicated by the shaded areas of the chart on page 35 should be included. The efficiency factors also should be included in calculations involving passives in the "near–field" and "closely–coupled" double passives. These efficiency reductions are not included in the graphs on pages 38 and 40.

Another common question is: "How do you know when a passive repeater is in the near–field of an antenna?" The graphs on page 39 are provided to make a rough determination of near–field distance (actually minimum far–field distance) where effective area, distance and frequency are related. Another "rule of thumb" sometimes helps: When the passive far–field gain is within 10dB of the free space loss calculated for the path, check for a near–field situation.

The final check for a near–field application should be made by calculating "1/K". (Refer to the graphs on page 40). If "1/K" is less than 2.5 the passive is in the near–field of the antenna. Note in actuality the transition from near–field to far–field is not a single distinct point in space but the "1/K=2.5" test is practical and accurate enough for system computations. At "1/K=2.5" the various curves on the graph very nearly come together.

For closely–coupled double passive repeater applications an effort should be made to make the effective areas nearly equal (as standard sizes allow) for the most efficient use of reflector areas. Also, the best configuration for the site and path angles should be selected from the figures on page 38. Note that the gain of the passive with the smaller effective area determines the net gain along with the close–coupling loss, α p.



CHAPTER III

RADIATION PATTERNS FOR PASSIVE REPEATERS

ABSTRACT -- A method for calculating radiation patterns for passive repeaters is presented. The method is intended for flat-faced reflectors typically used on microwave communications systems. As there is no apparent uniform method of determining interference conditions when passive repeaters are employed, the method described is suggested for general use in the telecommunications industry. The mathematics and plotting method are described with qualifications and assumptions. Some pattern plots from field measurements are compared with theoretical calculated plots. Examples of plotting methods are presented, and a suggested computer program is listed for convenient reference.

INTRODUCTION

The far-field radiation patterns of passive repeaters are those of a uniformly illuminated aperture. The reflector in infinite space may be viewed as the complement of an opening (aperture) in an infinite conducting screen.

The pattern plot reveals a distinct and significant major lobe (main beam) and side lobes with decreasing peak values. Radiation pattern plots and pattern envelope plots for passive repeaters are very similar in representation to plots made for parabolic microwave antennas. Refer to Figure 1 and Figure 2 for comparison of the pattern shapes in their typical graphical forms.

Patterns for passive repeaters vary with reflector sizes, carrier frequencies, and reflector shapes. Many passive repeaters used on systems employing microwave frequencies have very narrow beam widths. This fact makes them very compatible with large microwave antennas when interference conditions are investigated.

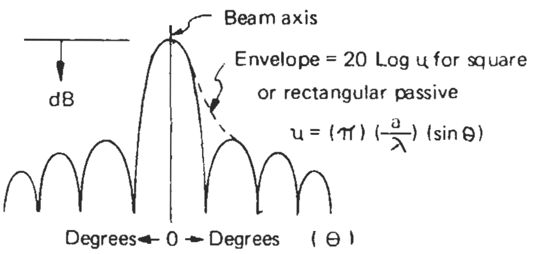
Rectangular reflector shapes are used most often for passive repeaters. Elliptical reflector shapes usually are preferred for periscope systems with a resulting circular aperture shape. Thus, emphasis is placed on rectangular shapes in this description of methods for radiation pattern plotting. However, the parameters for circular and rhombic shapes are described and exemplified.

PATTERNS NEAR THE "MAIN BEAM" AXIS

A general form of a pattern near the main beam axis can be developed for each aperture shape. A pattern cut in a principal plane is developed mathematically; whereby a parameter, "u", is related to the dimensions of the aperture and wavelength with consideration given to aperture shape. General plots for rectangular, circular, and rhombic apertures are depicted in Figures 3, 4 and 5 respectively. The general mathematical releationships for the plots are shown with each figure. These figures can be used to avoid plotting the curves each time a plot is desired. Only the scale for the angle, θ, requires change for each new set of values.

FIGURE 1

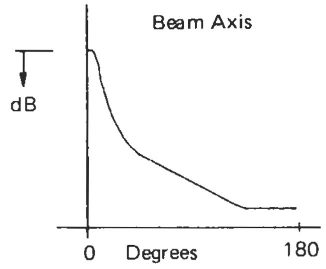
TYPICAL GRAPHICAL REPRESENTATIONS
PASSIVE REPEATER RADIATION



RECTANGULAR DECIBEL PLOT OF PATTERN

(for principal plane, near the beam axis)

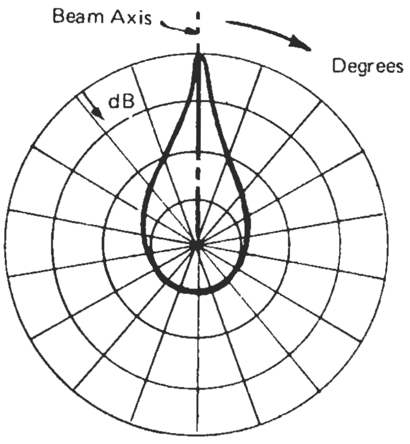
CALCULATED



PATTERN ENVELOPE PLOT

(rectangular decibel form)

CALCULATED



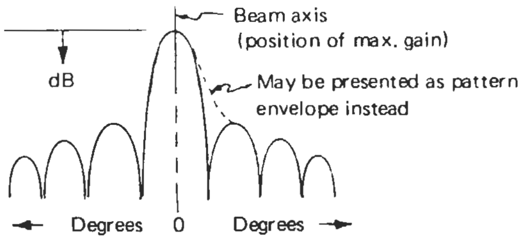
PATTERN ENVELOPE PLOT

(polar decibel form)

CALCULATED

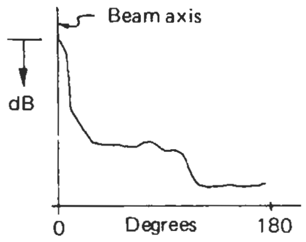
FIGURE 2

TYPICAL GRAPHICAL REPRESENTATIONS
MICROWAVE ANTENNA RADIATION



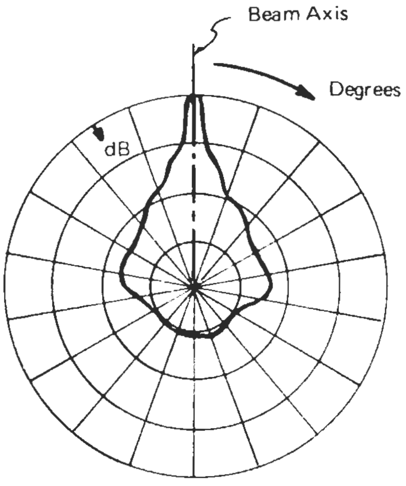
RECTANGULAR DECIBEL PLOT OF PATTERN

(for principal plane, near the beam axis)



PATTERN ENVELOPE PLOT

(rectangular decibel form)

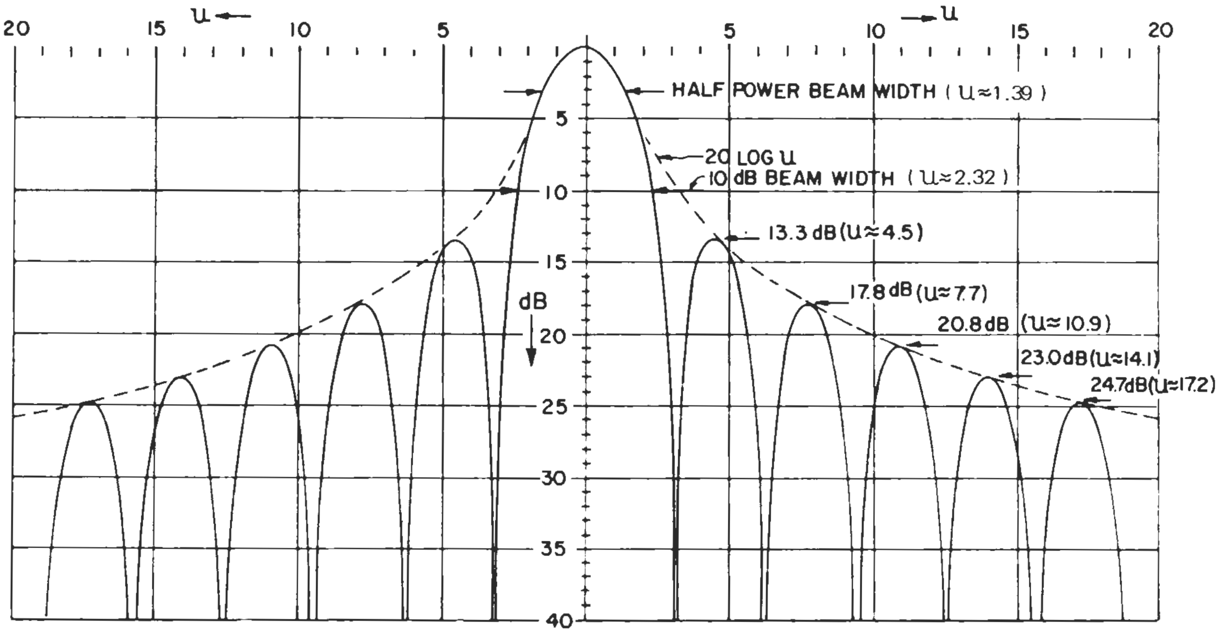


PATTERN ENVELOPE PLOT

(polar decibel form)

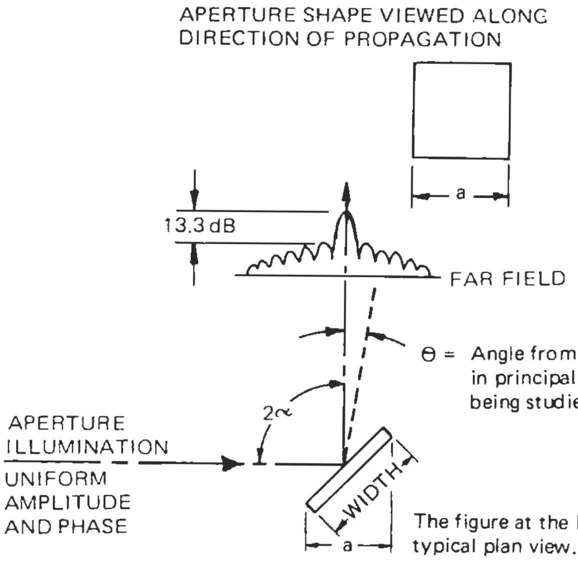
FIGURE 3

GENERAL RADIATION PATTERN
RECTANGULAR OR SQUARE PASSIVE REPEATERS



NOTE: THE NULL POSITIONS ARE AT $u = n\pi$, $n = 1, 2, 3, \cdots$

THE MINOR LOBE PEAKS ARE APPROXIMATELY AT $u = \frac{3\pi}{2}, \frac{5\pi}{2}, \frac{7\pi}{2}, \ldots$



θ = Angle from axis of main beam in principal plane of pattern being studied, degrees

The figure at the left shows a typical plan view. The pattern may be studied in the other principal plane (vertical) by using the effective height in place of "a"

a = (Width)(COS α)

$u = (\pi)\left(\frac{a}{\lambda}\right)(\sin\theta)$

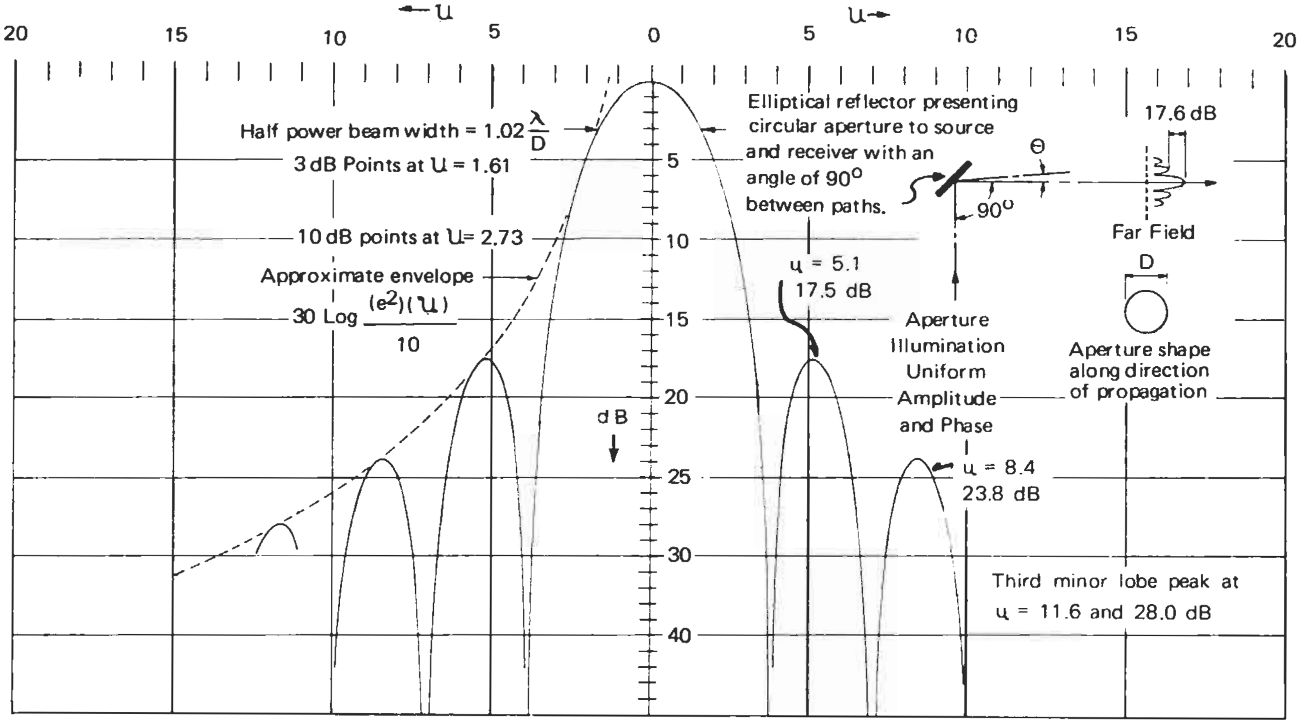
λ = WAVELENGTH = $\frac{0.9836}{f(\text{GHz})}$ (feet)

NORMALIZED POWER RADIATION PATTERN:

$\rho(u) = \left(\frac{\text{SIN}\ u}{u}\right)^2$ FOR RECTANGULAR OR SQUARE APERTURES

FIGURE 4

GENERAL RADIATION PATTERN PASSIVE REPERATERS WITH CIRCULAR APERTURE



D = Diameter of aperture

$U = (\pi)(\frac{D}{\lambda})(\sin\Theta)$, λ = Wavelength

Θ = Angle from axis of main beam in the plane of pattern being studied

Normalized power radiation pattern:

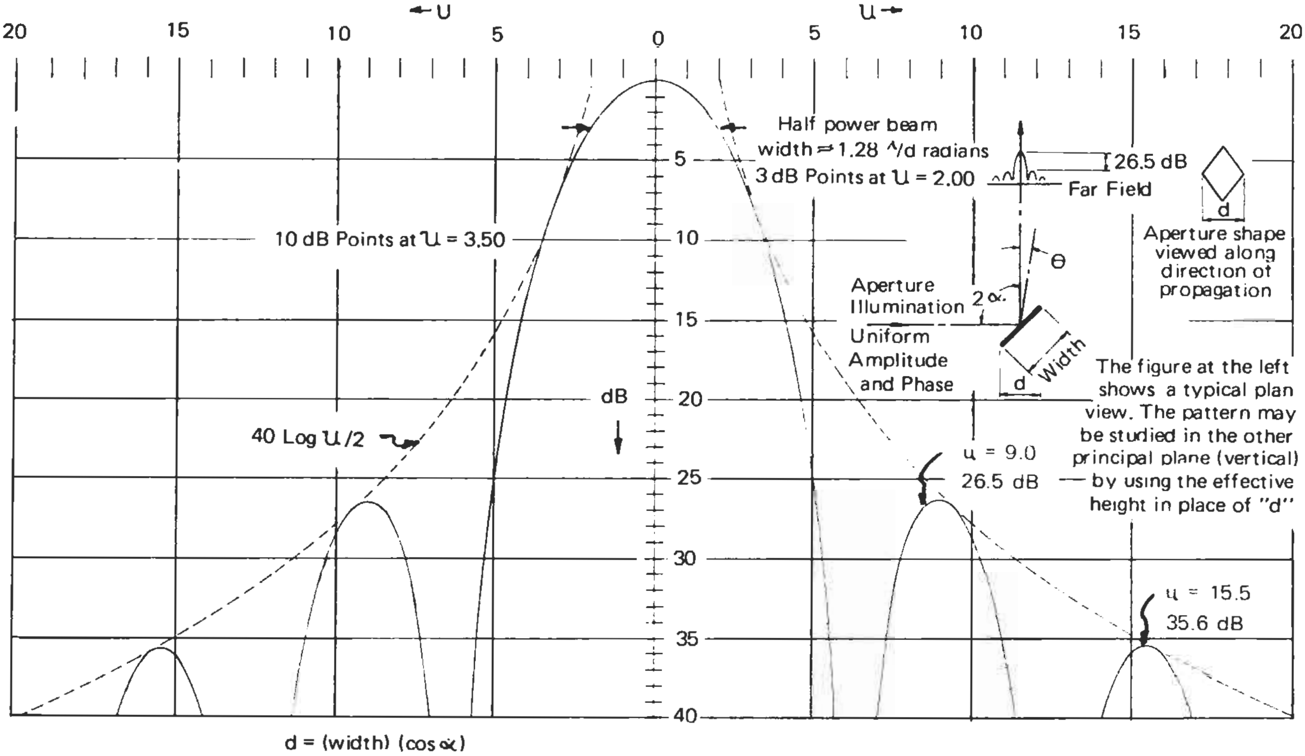
$$\rho(u) = [\Lambda_1(u)]^2$$

$$\Lambda_1(u) = \frac{2}{u} J_1(u)$$

$$J_1(u) = \frac{u}{2\cdot 0!\cdot 1!} - \frac{u^3}{2^3\cdot 1!\cdot 2!} + \frac{u^5}{2^5\cdot 2!\cdot 3!} - \dots$$

FIGURE 5

GENERAL RADIATION PATTERN RHOMBIC PASSIVE REPEATERS



d = (width) (cos α)

$U = (\pi)(\frac{d}{\lambda})(\sin\Theta)$, λ = Wavelength

Θ = Angle from axis of main beam in principal plane of pattern being studied

Normalized power radiation pattern: $f(U) = (\frac{\sin U/2}{U/2})^4$

EXPLANATION OF MATHEMATICAL RELATIONSHIPS LIMITATIONS, QUALIFICATIONS AND ASSUMPTIONS

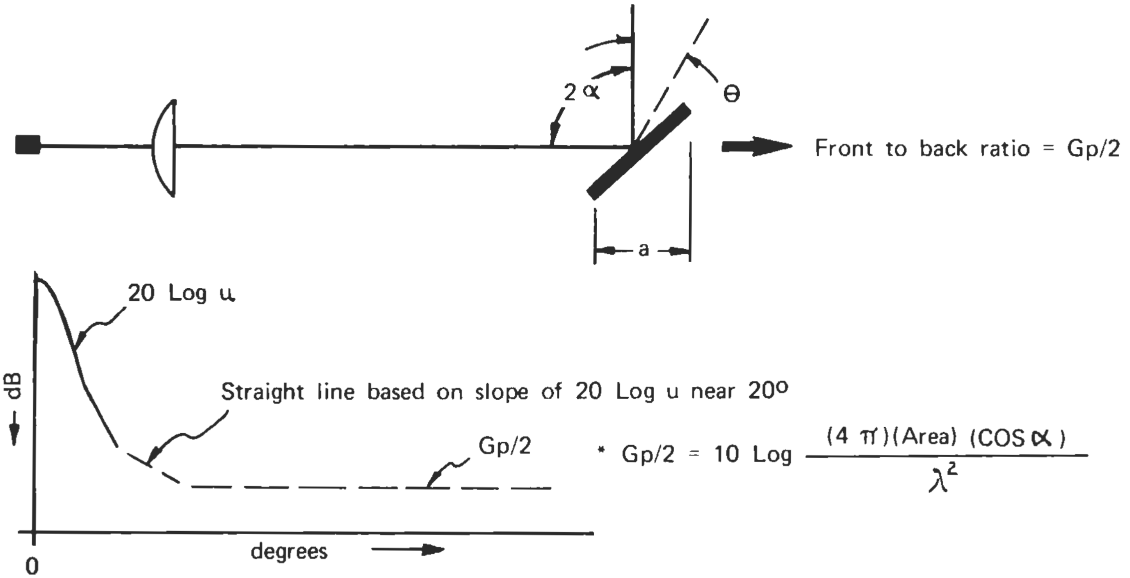
Before the mathematical relationships shown on Figures 3, 4, and 5 are used to make pattern and pattern envelope plots, the limitations of the formulas should be understood. The formulas cannot be used for developing a plot for "θ" values to 180° on a rectangular plot or 360° on a polar plot. Nor can three-dimensional plots be developed from the information. The original assumptions made for the development of the formulas require that only small angular deviations from the major lobe axis be considered for very accurate results. Uniform illumination by a plane wavefront also is required (passive repeater in far-field of antenna). It has been proven that the formulas yield good results for far-field patterns of rectangular passives to the 5th minor lobe, and the trends of the measured patterns indicate a probability of good accuracies for pattern envelopes to 30 or 40 minor lobes for many applications. A high degreee or correlation between calculated data and measured data is exemplified by figures 7 and 8.

In order to obtain complete calculated pattern envelopes it is necessary to devise an approximate method that yields practical results for most applications of passive repeaters. Of course, the practicality of the approximations depends upon the use of the information; some interference investigations have simplifying assumptions in methods that would not justify requiring extreme accuracies for pattern envelopes of all devices. A neglected obstruction may be more significant by several dB than the inaccuracy of the calculated pattern: direct energy from an antenna illuminating a passive repeater may be more harmful than energy reflected from the passive.

The general functions for evaluating the envelope of the minor lobe peaks are indicated on Figures 3, 4, and 5, such as, "20 Log u" for a rectangular aperture in Figure 3. For most passive repeater applications (rectangular in shape) it is probable that "20 Log u" will yield results of practical accuracies for "θ" values to 20°. Also one-half the two-way gain, Gp/2, can be used as a theoretical front-to-back ratio. Thus, the pattern envelope could be represented in the manner illustrated by Figure 6.

A computer program listing using the procedures illustrated by Figure 6 is shown on page 49.

FIGURE 6



$$* \; Gp/2 = 10 \text{ Log } \frac{(4\pi)(\text{Area})(\text{COS } \alpha)}{\lambda^2}$$

RADIATION PATTERN ENVELOPE
(RECTANGULAR OR SQUARE PASSIVE)

$$u = (\pi)\left(\frac{a}{\lambda}\right)(\sin \theta)$$

$$a = (\text{Length})(\text{COS } \alpha)$$

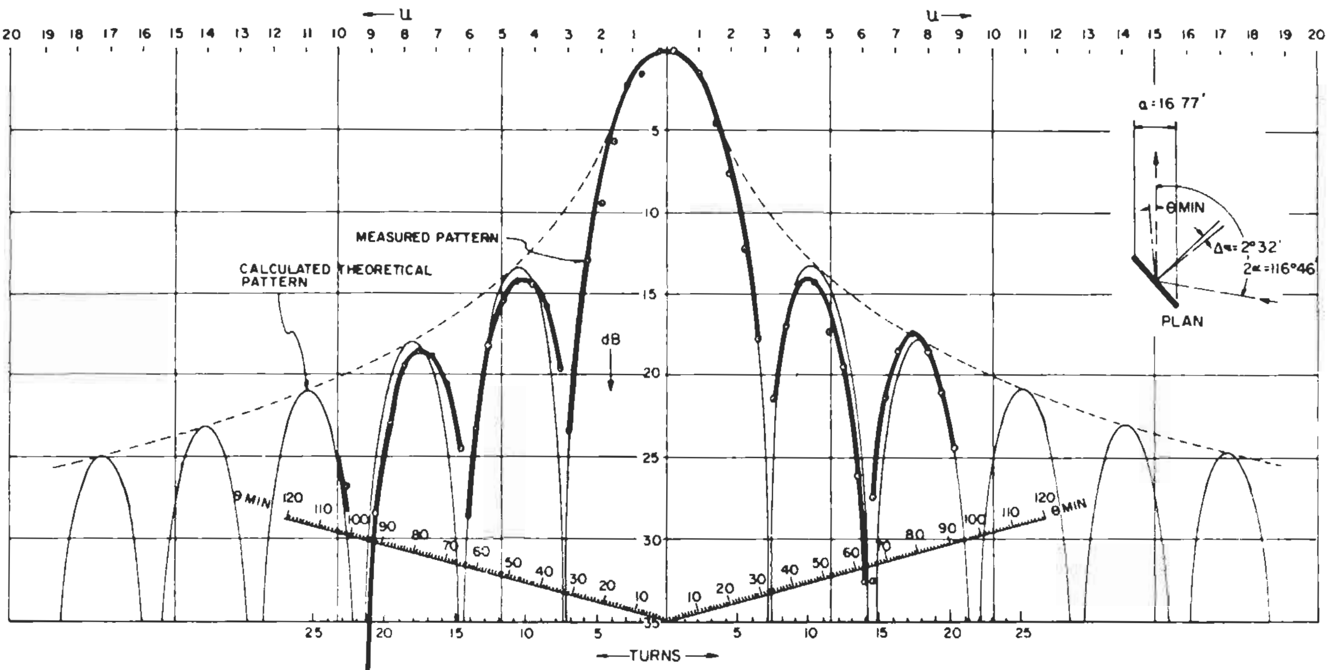
For vertical cut in principal plane and small passive face angles (tilt):

a = Height

* Sometimes the effective area, A cos α, should be computed taking into account the actual angle between incident and reflected beams, rather than the horizontal included angle, 2 α. This may be adviseable when one or both beam paths are in excess of 20° from the horizontal. Effective aperture size in the vertical plane must also be appropriately adjusted from nominal reflector height for extreme vertical angle.

See page 50 for figure illustrating path geometry and computations for effective area using the actual angle between incident and reflected energy.

FIGURE 7



$u = (a)\left(\frac{\pi}{\lambda}\right)(\sin\theta)$

$u \approx \frac{(a)(\theta\,\mathrm{MIN})}{(1094)(\lambda)}$

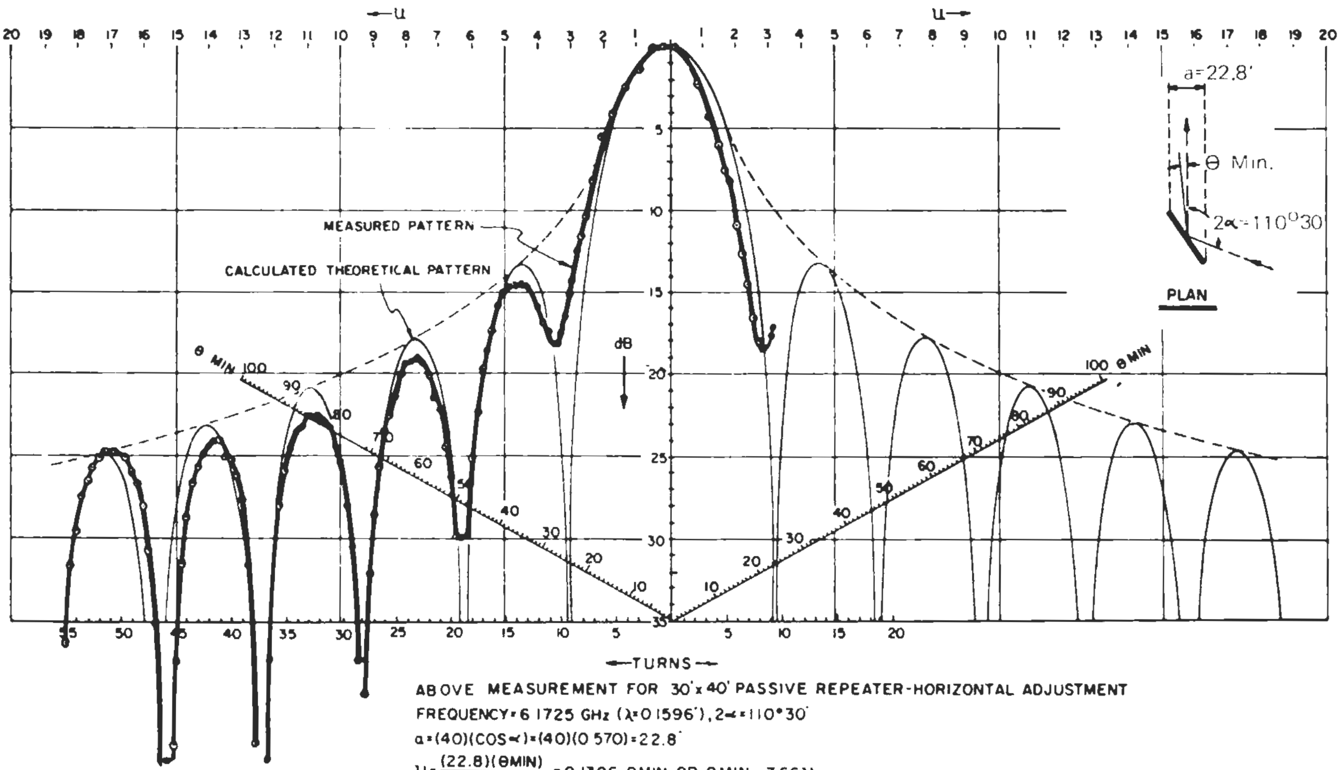
ABOVE MEASUREMENTS FOR 20'x32' PASSIVE REPEATER - HORIZONTAL ADJUSTMENTS
FREQUENCY = 6.1725 GHz (λ = 0.1596'), 2α = 116° 46'
$a = (32)(\cos\alpha) = (32)(0.524) = 16.77'$

$u = \frac{(16.77)(\theta\,\mathrm{MIN})}{(1094)(0.1596)} = 0.09605$ OR θMIN = 10.41u

CHARACTERISTICS OF ADJUSTING MECHANISM
1 TURN = 2.24' - CORRESPONDS TO θMIN = 4.48

θMIN = ANGLE θ IN MINUTES OF ARC

FIGURE 8



ABOVE MEASUREMENT FOR 30'x40' PASSIVE REPEATER - HORIZONTAL ADJUSTMENT
FREQUENCY = 6.1725 GHz (λ = 0.1596'), 2α = 110°30'
$a = (40)(\cos\alpha) = (40)(0.570) = 22.8'$

$u = \frac{(22.8)(\theta\,\mathrm{MIN})}{(1094)(0.1596)} = 0.1306\ \theta\mathrm{MIN}$ OR θMIN. = 7.66u

CHARACTERISTICS OF ADJUSTING MECHANISM
1 TURN = 1.28 MINUTES - CORRESPONDS TO θMIN. = 2.56
θMIN = ANGLE θ IN MINUTES OF ARC

$u = (a)\left(\frac{\pi}{\lambda}\right)(\sin\theta)$

$u = \frac{(a)(\theta\,\mathrm{MIN})}{(1094)(\lambda)}$

Computer Program Listing for Suggested Radiation Pattern Plots of Rectangular Passive Repeaters

```
10 REM PROGRAM DEVELOPED BY MICROFLECT CO. INC., SALEM, OREGON
20 DIM A$[10]
30 DEG
40 FIXED 2
50 FORMAT 5/
60 WRITE (15,50)
70 PRINT "    RADIATION PROGRAM WRITTEN FOR THE HEWLETT-PACKARD 9830A COMPUTER,
80 PRINT "              USING THE H-P VERSION OF THE 'BASIC' LANGUAGE"
90 PRINT "              *********************************************"
100 WRITE (15,50)
110 DISP "FREQUENCY IN GHZ";
120 INPUT F
130 DISP "PASSIVE SIZE (V,H) IN FEET";
140 INPUT W1,W2
150 DISP "'H'ORIZONTAL OR 'V'ERTICAL CUT";
160 INPUT A$
170 IF A$="V" THEN 230
180 A$="HORIZONTAL"
190 DISP "HORIZONTAL INCLUDED ANGLE (DEG)";
200 INPUT A
210 E=W2*COS(A/2)
220 GOTO 270
230 A$="VERTICAL"
240 DISP "VERTICAL INCLUDED ANGLE (DEG)";
250 INPUT A
260 E=W1*COS(A/2)
270 WRITE (15,280)F
280 FORMAT 10X,"MICROWAVE FREQUENCY =",F7.3," GHZ.",/
290 WRITE (15,300)W1,W2
300 FORMAT 10X,"PASSIVE REPEATER SIZE =",F3.0," X",F3.0," FEET",/
310 WRITE (15,320)A$
320 FORMAT 10X,"PLANE OF DESIRED RADIATION PATTERN: ",F1.0
330 WRITE (15,340)A
340 FORMAT /,10X,"INCLUDED ANGLE BETWEEN PATHS =",F7.2," DECIMAL DEGREES",2/
350 WRITE (15,360)E
360 FORMAT 10X,"(EFFECTIVE APERTURE AREA =",F7.2," SQ. FT.)",5/
370 U1=10*LGT(4*PI*W1*W2*COS(A/2)*F↑2/0.9836↑2)
380 PRINT "          RADIATION PATTERN FROM PEAK TO FOURTH MINOR LOBE"
390 PRINT "                     (IN DECIBELS DOWN FROM PEAK)"
400 WRITE (15,410)
410 FORMAT /,X,"DEG",53X,"ZERO DB *",/
420 FOR T=0.001 TO 100 STEP 0.02
430 U=F/0.9836*PI*E*SINT
440 P=10*LGT((U/SIN(U*180/PI))↑2)
450 IF P>30 THEN 480
460 PRINT T;TAB(2*(30-P)+6)"* ";-P
470 GOTO 500
480 PRINT T;-P
490 REM  U=14.1 IS APPROXIMATELY THE PEAK OF THE FOURTH MINOR LOBE
500 IF U >= 14.1 THEN 520
510 NEXT T
520 WRITE (15,530)
530 FORMAT 2/,10X,"PATTERN ENVELOPE FROM FOURTH MINOR LOBE TO 180 DEGREES",/
540 FOR I=INTT+1 TO 21 STEP 2
550 K=U
560 REM 20*LGT(U) IS THE PATTERN ENVELOPE
570 U=20*LGT(PI*E*F/0.9836*SINI)
580 IF U >= U1 THEN 610
590 PRINT I;TAB(86-U)"* ";-U
600 NEXT I
610 M=(K-U)/2
620 FOR J=I TO 150 STEP 5
630 REM  THE CURVE NOW DECREASES LINEARLY
640 U=U-M*2.5
650 IF U <= U1 THEN 670
660 GOTO 690
670 PRINT J;TAB(86-U)"* ";-U
680 NEXT J
690 REM  THE PATTERN NOW HOLDS CONSTANT AT THE FRONT-TO-BACK RATIO
700 FOR I=J TO 180 STEP 10
710 PRINT I;TAB(86-U1)"* ";-U1
720 NEXT I
730 PRINT 180;TAB(86-U1)"* ";-U1
740 WRITE (15,50)
750 END
```

FAR-FIELD, NEAR-FIELD PATTERN DIFFERENCES

In this presentation emphasis is placed on far-field radiation patterns. However, it is worthwhile to consider the effects on the radiation pattern when a passive reflector is in the near-field of an antenna. In general the major lobe may be slightly broader, the peaks of the minor lobes near the major lobe axis will be raised a few dB, and the nulls will fill-in. See Figure 9 for a general comparison of far-field and near-field patterns.

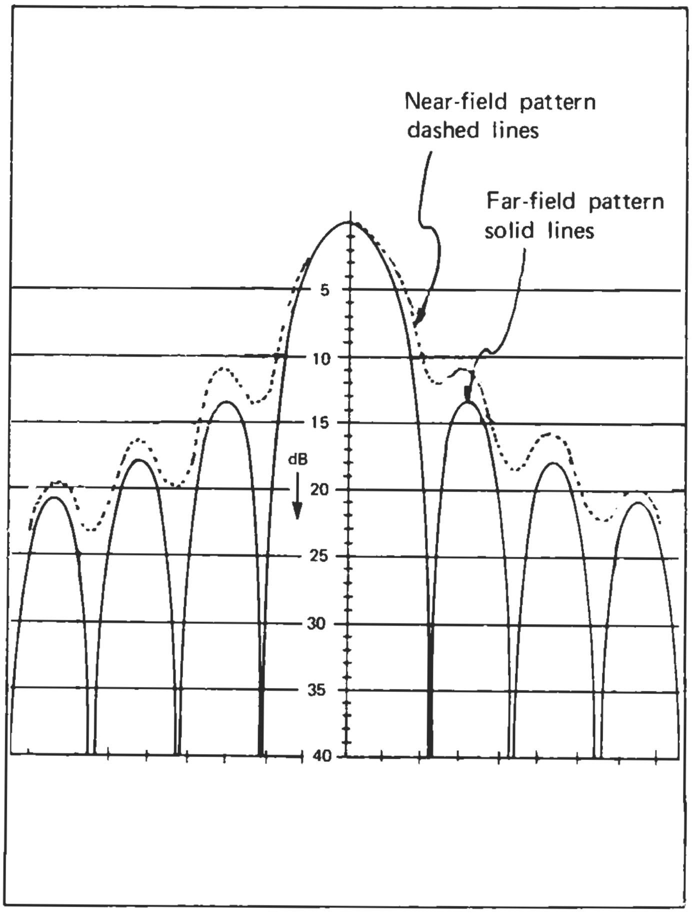


FIGURE 9

GENERAL COMPARISON
FAR-FIELD, NEAR-FIELD PATTERNS

An exact evaluation for each near-field application is very difficult to accomplish. However, an awareness of the general effects on patterns due to near-field applications would allow for some practical engineering judgments. The following adjustments to the far-field pattern envelope might be used:

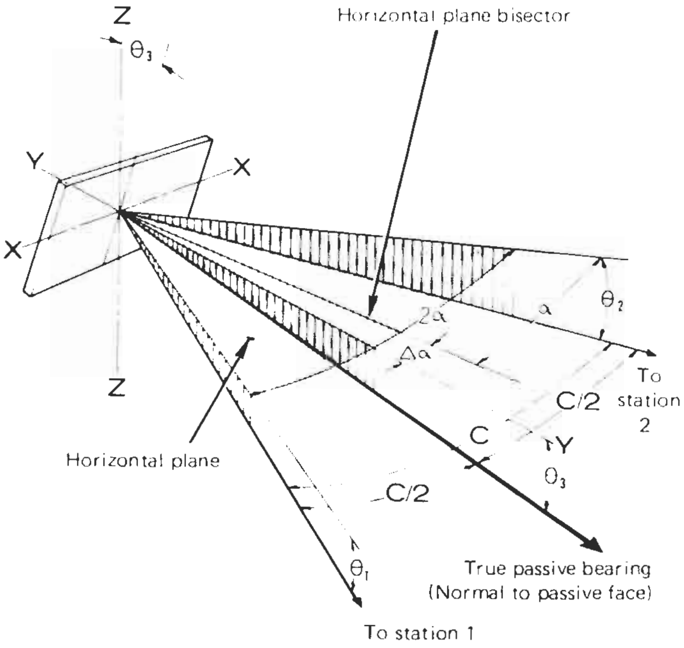
a. Raise 1st and 2nd minor lobe peaks 3dB

b. Raise 3rd, 4th, and 5th minor lobe peaks 2dB

c. Raise pattern envelope from 6th minor lobe peak to $\theta = 20^\circ$ 1 dB

d. Use far-field pattern from $\theta = 20^\circ$ to $\theta = 180^\circ$

PATH GEOMETRY AND EFFECTIVE AREA COMPUTATIONS



PATH GEOMETERY

The angle C may be evaluated from the following relationships:

$$\cos C/2 = \frac{\sin \theta_1 + \sin \theta_2}{2 \sin \theta_3}$$

where: θ_1 is the least vertical path angle

θ_2 is the greatest vertical path angle

θ_3 is the vertical face angle of the passive.

θ_1 and θ_2 may be measured or may be calculated from the site elevations and path lengths, and θ_3 is calculated from the following:

$$\tan \Delta\alpha = \frac{(\tan \alpha)(\cos \theta_1 - \cos \theta_2)}{(\cos \theta_1 + \cos \theta_2)}, \text{ and}$$

$$\tan \theta_3 = \frac{(\cos \Delta\alpha)(\sin \theta_1 + \sin \theta_2)}{(\cos \alpha)(\cos \theta_1 + \cos \theta_2)}$$

Sign convention: all cosines positive. Sines are positive when the angle from the passive is below the horizontal and negative when above.

$$\text{Passive repeater gain} = 20 \text{ Log } \frac{(4\pi)(\text{Area})(\text{COS } \frac{C}{2})}{\lambda^2}$$

POLARIZATION EFFECTS ON PATTERNS

Concern often is expressed that pattern envelopes may vary significantly for various types of polarization of the propagated wave. In general it is practical to assume there is no significant difference in patterns between vertical and horizontal polarizations for linearly polarized systems.

PLOTTING PATTERNS

The graphical representations of Figure 1(page44) illustrate three convenient forms of plotting radiation patterns and pattern envelopes. The rectangular decibel plots often are used for convenience in extracting specific values from the graphs, but polar plots provide a better visualization of the spacial distribution of the pattern envelope.

The rectangular decibel plot of the pattern near the main beam axis (center of major lobe) provides specific values of off-axis radiation levels for small angular deviations from the peak of the major lobe. This information is helpful for evaluation of structural rigidity requirements, alignment procedures, interference conditions, and response to angle–of–arrival changes of the wavefront. Unless the angular scale is carefully observed on this plot, a misleading general impression that a passive repeater pattern is very broad may be derived from the appearances of the graphical representation.

The following pattern plotting procedures and examples are for cuts in a principal plane, usually a horizontal or vertical plane. Thus, the normalized power patterns are a function of the aperture dimension in one of the principal planes.

To make pattern plots the information in Figures 3, 4, and 5 can be very useful. Copies of the graphs can be made on an office copier and used for plotting patterns near the major lobe axis. The appropriate scales for the angle, "θ", are affixed to the copies of the graphs in accordance with the effective aperture size and wavelength. In other words, the graphs are general for the shape of the aperture shown ,and there is no need to plot the curves for each application; only the scale for "θ" varies. The angular scale for "θ" can also be translated to a scale for turns of a particular adjusting mechanism. The mathematical relationships are shown in each of Figures 3, 4, and 5 for calculating the angle, θ, in terms of the aperture size, wavelength of the propagated wavefront, and the general parameter, "u".

The following examples illustrate plotting procedures.

EXAMPLE 1

Given:

24 feet high by 30 feet wide rectangular passive repeater

frequency = 6.175 GH_z

horizontal included angle (2α) between incident and reflected beams is 90° ($\alpha = 45^\circ$)

Required:

Pattern and Pattern Envelope in horizontal plane

$$\text{Gain, Gp, at 100\% efficiency} = 20 \text{ Log } \frac{4\pi A \cos\alpha}{\lambda^2}$$

$$\lambda = \frac{0.9836}{f \text{ GH}_\text{z}} \text{ feet} = \frac{0.9836}{6.175} = 0.1593 \text{ feet}$$

$$\text{Gp} = 20 \text{ Log } \frac{(4\pi)(24)(30)(\cos 45^\circ)}{(0.1593)^2} = 108 \text{ dB}$$

Front-to-back ratio assumed to be

Gp/2 = 108/2 = 54 dB

Effective aperture size, a = (width) ($\cos\alpha$)

a = (30) ($\cos 45^\circ$) = 21.21 feet

$$u = (\pi)\left(\frac{a}{\lambda}\right)(\sin\Theta) = (\pi)\left(\frac{21.21}{0.1593}\right)(\sin\Theta)$$

$u = 418.4 \sin\theta$ or $\sin\theta = 0.00239\, u$

3 dB points at $u = 1.39$; $\theta = 0.19^\circ$

HALF–POWER BEAM WIDTH = (2) (0.19) = 0.38 °

10 dB points at $u = 2.32$; $\theta = 0.32^\circ$
(common reference for structural rigidity requirements)

40 dB points at $u = 3.11$; $\theta = .43^\circ$
(this angle of "θ" very near 1st null point in pattern)

Minor Lobe	"u" at Lobe Peak	20 Log u	θ degrees
1	4.5	13.3	0.62
2	7.7	17.8	1.05
3	10.9	20.8	1.49
4	14.1	23.0	1.93
5	17.2	24.7	2.36
		37	10
		41	15
		43	20
		45	25

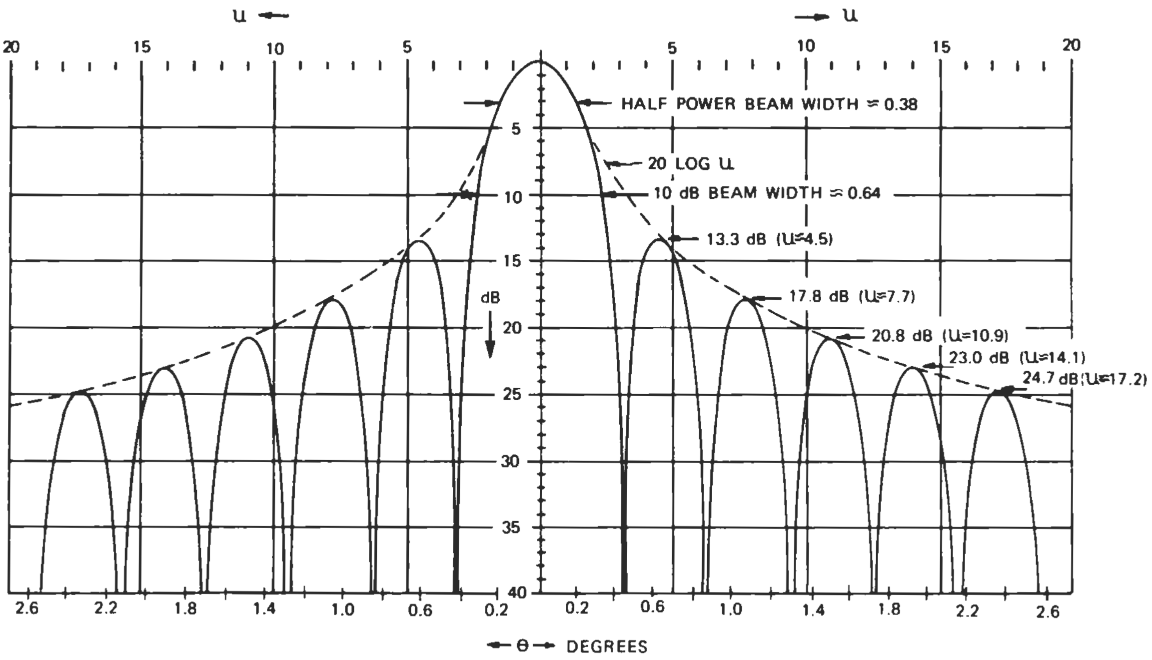
from $\theta = 20^\circ$ to front-to back ratio (54 dB) use slope of

$$\frac{45\text{-}41}{10} = 0.4 \text{ dB/degree}$$

SEE FIGURE 10 FOR PLOTS

FIGURE 10

PATTERN AND PATTERN ENVELOPE PLOTS FOR EXAMPLE NO. 1



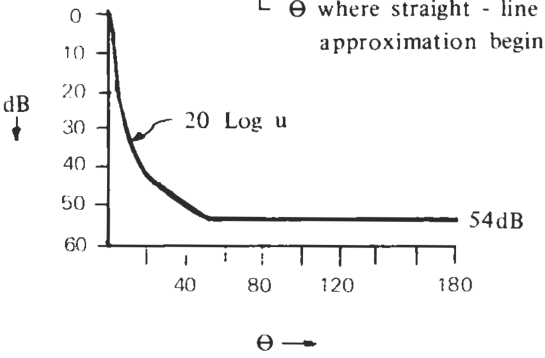
RADIATION PATTERN FOR EXAMPLE NO. 1
24 feet x 30 feet Rectangular Passive Repeater
f = 6.175 GHz, 2 ∝ = 90°

$$\frac{54 - 43}{0.4} = 28$$

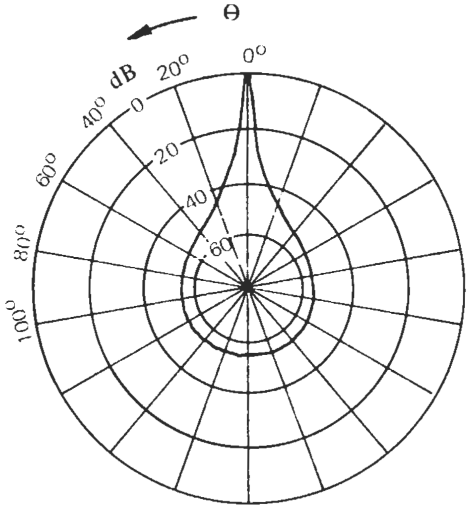
20 + 28 = 58°

θ at 54 dB

θ where straight - line approximation begins



PATTERN ENVELOPE
EXAMPLE NO. 1



PATTERN ENVELOPE
EXAMPLE NO. 1

EXAMPLE 2

Given:

Periscope System -
Flat-Face 10ft x 15ft Elliptical Reflector
Geometry of system is such that reflector aperture is circular (D = 10ft)
frequency = 6.175 GH_Z

Required:

Pattern and Pattern Envelope
(In this case assumed identical for horizontal and vertical planes)

Far-Field Gain, Gp, at 100% Eff. = 20 Log $\dfrac{4\pi A_e}{\lambda^2}$

Ae = effective area = $\dfrac{\pi D^2}{4} = \dfrac{(\pi)(10)^2}{4}$ = 78 Sq. Ft.

$\lambda = \dfrac{0.9836}{f\ \text{GH}_\text{Z}}$ feet $= \dfrac{0.9836}{6.175}$ = 0.1593 ft.

$\text{Gp} = 20 \text{ Log } \dfrac{(4\pi)\ (78)}{(0.1593)^2} \approx 92 \text{ dB}$

Front-to back ratio = Gp/2 = 92/2 = 46 dB

$u = (\pi)(\dfrac{D}{\lambda})(\sin\Theta) = (\pi)(\dfrac{10}{0.1593})(\sin\Theta)$

u = 197.2 sin θ or sin θ = 0.00507 u

3 dB points at u = 1.61: θ = 0.47 °

HALF-POWER BEAM WIDTH = (2) (0.47) = 0.94 °

10 dB points at u = 2.73; θ = 0.79 °

Minor Lobe	"u" at Lobe Peak	30 Log $\dfrac{e^2\ u}{10}$	θ degrees
1	5.1	* 17.5	1.5
2	8.4	* 23.8	2.4
		* 39	8
		* 42	10
		44	12

from θ = 10° to front-to-back ratio (46 dB) use

slope of $\dfrac{44\text{-}39}{4}$ = 1.25 dB/degree

$\dfrac{46\text{-}42}{1.25} \approx 3°$

Pattern envelope at
46 dB from 13 ° to 180 °

* Some adjustments should be made for near-field application

SEE FIGURE 11 FOR PLOTS

EXAMPLE 3

Given:

Periscope System -
Flat-Face 10ft x 15ft Rectangular Reflector
Geometry of system is such that reflector aperture is square
frequency = 6.175 GH_Z

Required:

Pattern and Pattern Envelope
(In this case assumed identical for horizontal and vertical planes)

Far-Field Gain, Gp, at 100% Eff. = 20 Log $\dfrac{4\pi A_e}{\lambda^2}$

Ae = effective area = (10) (10) = 100 Sq. Ft.

$\lambda = \dfrac{0.9836}{f\ \text{GH}_\text{Z}}$ feet $= \dfrac{0.9836}{6.175}$ = 0.1593 ft.

$\text{Gp} = 20 \text{ Log } \dfrac{(4\pi)(100)}{(0.1593)^2} \approx 94 \text{ dB}$

Front-to-back ratio = Gp/2 = 47 dB

$u = (\pi)(\dfrac{a}{\lambda})(\sin\Theta) = (\pi)(\dfrac{10}{0.1593})(\sin\Theta)$

u = 197.2 sin Θ <u>or</u> sin Θ = 0.00507 u

3 dB points at u = 1.39: θ = 0.40 °

HALF-POWER BEAM WIDTH = (2) (0.40) = 0.80 °

10 dB points at u = 2.32; θ = 0.67°

Minor Lobe	"u" at Lobe Peak	20 Log u	θ degrees
1	4.5	* 13.3	1.3
2	7.7	* 17.8	2.2
3	10.9	* 20.8	3.2
4	14.1	* 23.0	4.1
5	17.2	* 24.7	5.0
		* 31	10
		* 34	15
		* 37	20
		38	25

from θ = 20 ° to front-to back ratio (47 dB) use slope of

$\dfrac{38\text{-}34}{10}$ = 0.4 dB degree

$\dfrac{47\text{-}37}{0.4}$ = 25 °

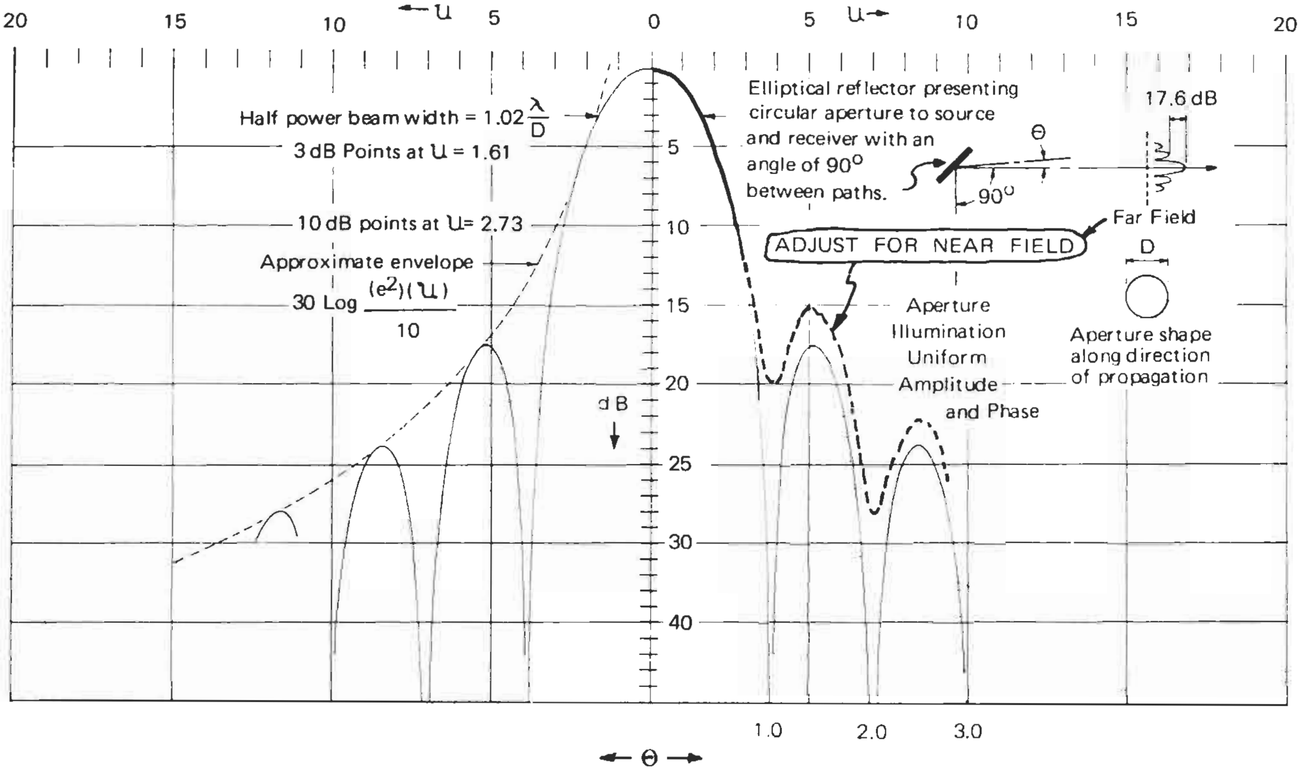
Pattern envelop at
47 dB from 45 ° to 180 °

* Some ajustments should be made for near-field application.

SEE FIGURE 12 FOR PLOTS

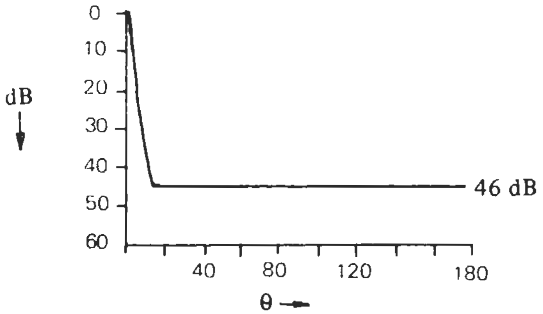
FIGURE 11

PATTERN AND PATTERN ENVELOPE PLOTS FOR EXAMPLE NO.2

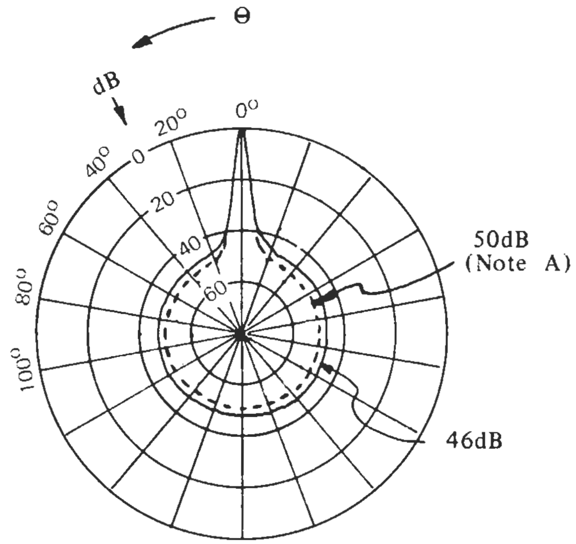


RADIATION PATTERN FOR EXAMPLE NO. 2

10 feet x 15 feet Elliptical Reflector (Periscope System)



PATTERN ENVELOPE
EXAMPLE NO. 2



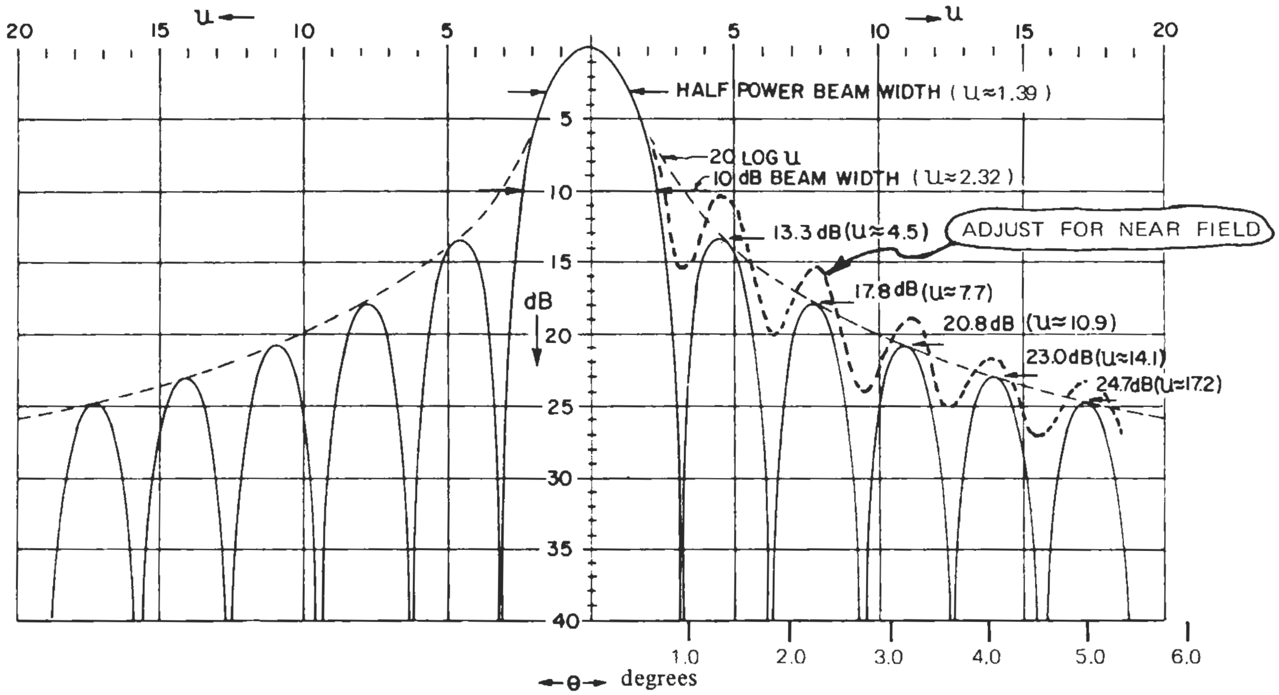
PATTERN ENVELOPE
EXAMPLE NO. 2

NOTE A

The spacing of the antenna and reflector along with compatible shapes in a highly efficient combination could justify the front-to-back ratio indicated by the dotted line of the envelope plot.

FIGURE 12

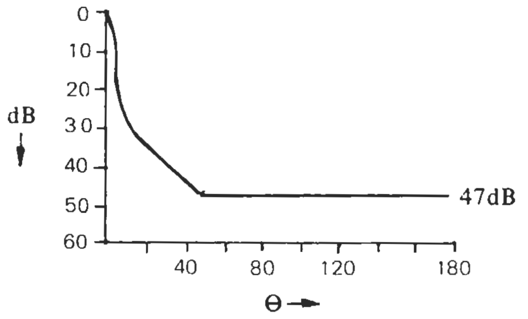
PATTERN AND PATTERN ENVELOPE PLOTS FOR EXAMPLE NO. 3



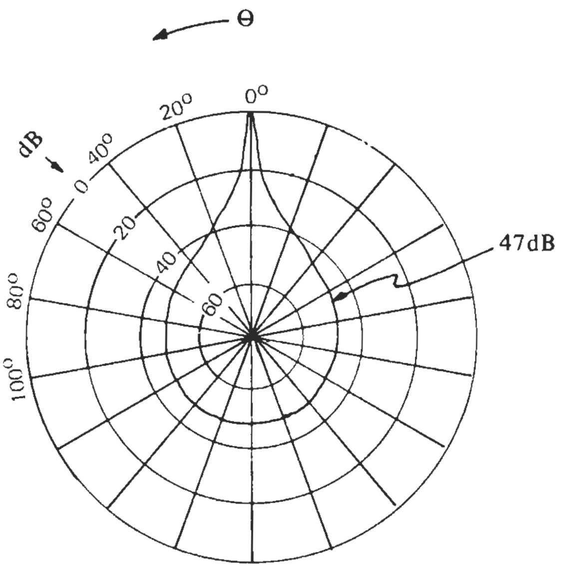
RADIATION PATTERN FOR EXAMPLE NO. 3

10 feet x 15 feet Rectangular Reflector (Periscope System)

f = 6.175 GH_Z



PATTERN ENVELOPE
EXAMPLE NO. 3



PATTERN ENVELOPE
EXAMPLE NO.3

EXAMPLE 4

Given:

16 feet high by 24 feet wide rhombic passive repeater
frequency = 6.175 GH_Z
horizontal included angle (2α) between incident and reflected beams is 120° ($\alpha = 60^\circ$)

Required:

Pattern and Pattern Envelope in horizontal plane

$$\text{Gain, Gp, at 100\% eff.} = 20 \text{ Log } \frac{4\pi A\cos\alpha}{\lambda^2}$$

$$\lambda = \frac{0.9836}{f\text{GH}_\text{Z}} \text{ feet } = \frac{0.9836}{6.175} = 0.1593 \text{ ft.}$$

$$\text{Gp} = 20 \text{ Log } \frac{(4\pi)(12)(16)(\cos 60^\circ)}{(0.1593)^2} \approx 94\text{dB}$$

front-to-back ratio assumed to be
$\text{Gp}/2 = 94/2 = 47$ dB

Effective aperture size, d = (width) ($\cos\alpha$)

$d = (24)(\cos 60\ ) = 12.0$ feet

$$u = (\pi)\left(\frac{d}{\lambda}\right)(\sin\theta) = (\pi)\left(\frac{12.0}{0.1593}\right)\sin\theta$$

$u = 236.7 \sin\theta$ or $\sin\theta = 0.00423\ u$

3 dB points at $u = 2.00$; $\theta = 0.49^\circ$

HALF-POWER BEAM WIDTH = (2) (0.49) = 0.98°

10 dB points at $u = 3.50$; $\theta = 0.85^\circ$

Minor Lobe	"u" at Lobe Peak	40 Log u/2	θ degrees
1	9.0	26.5	2.2
2	15.5	35.6	3.8
		40.5	5
		43.7	6
		46.4	7
		47.0	7.3

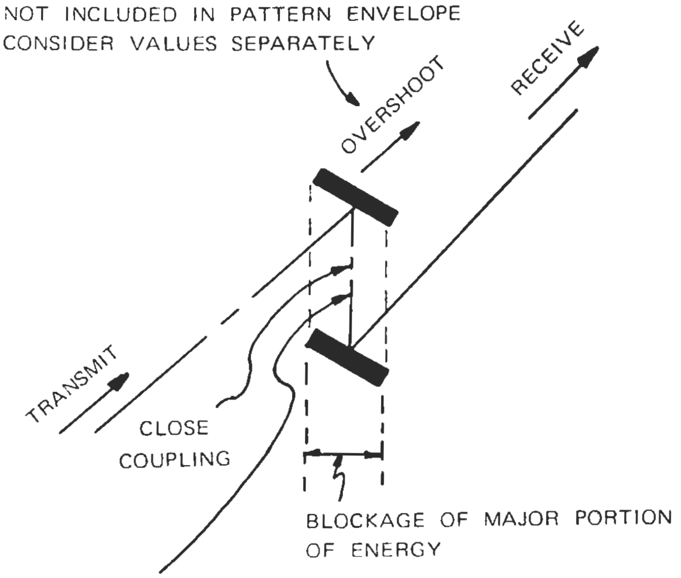
SEE FIGURE 13 FOR PLOTS

COMMENTS ON EXAMPLES AND CLOSELY COUPLED DOUBLE PASSIVES

The examples display relative values of radiation levels for pattern envelopes that are reasonable for the applications shown. However, the approximations made to complete the envelope are simple and not substantiated by tests, which would tend to make the patterns optimistic for some parts of interference investigations and conservative for some of the angles investigated. For example, actual reflector panel edge construction would cause the pattern to be slightly unsymmetrical.

It is worthwhile to note also that front-to-back ratios may be better than the examples display for periscope systems with spacing and relative shape of antenna and reflector engineered for high efficiency. The high efficiency of the antenna reflector combination would indicate that little energy is available for radiation in undesired directions. Thus, it may be justifiable to use a higher front-to back ratio than that shown in Example No. 2.

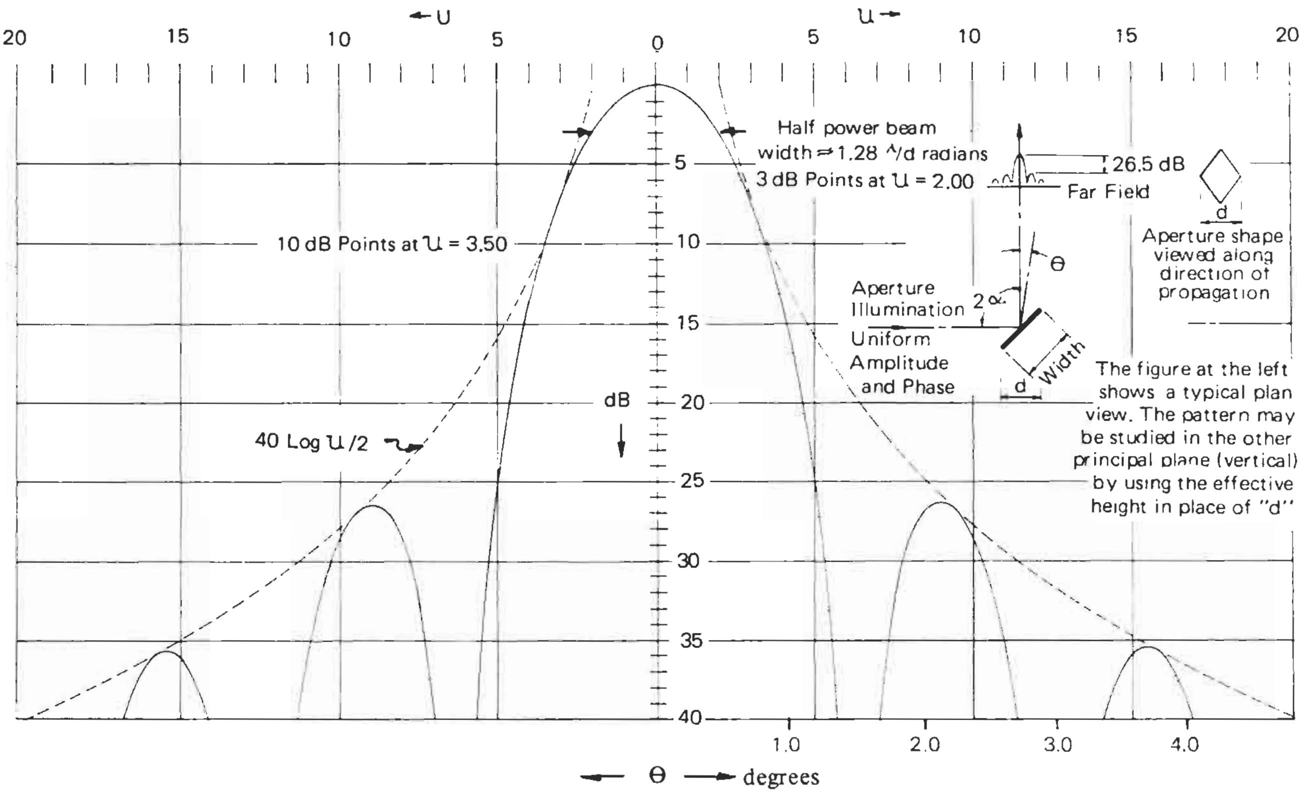
FOR CLOSELY SPACED DOUBLE PASSIVE REPEATERS IT IS LOGICAL TO USE THE FAR-FIELD PATTERN OF ONE OF THE PASSIVES ONLY FOR INTERFERENCE STUDIES. THE PASSIVE USED WOULD DEPEND UPON THE DIRECTION OF TRANSMISSION. THIS APPROACH MAY BE JUSTIFIED BY CONSIDERING ENERGY FROM THE FIRST PASSIVE ENCOUNTERED BY THE WAVE-FRONT CAN BE RADIATED ONLY AT VERY LOW LEVELS DUE TO BLOCKING BY THE SECOND PASSIVE.



IF DISTANCE IS FAR ENOUGH THE VALUE OF "20 LOG U" IN THE UN-BLOCKED ANGLES COULD BE USED FOR THE FIRST PASSIVE TO THE LEVEL OF THE FRONT TO BACK RATIO OF THE SECOND PASSIVE ENCOUNTERED BY THE ENERGY.

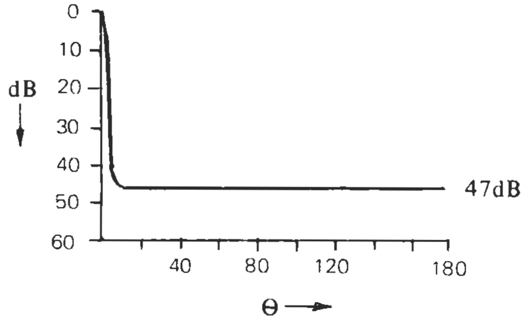
FIGURE 13

PATTERN AND PATTERN ENVELOPE PLOTS FOR EXAMPLE NO. 4

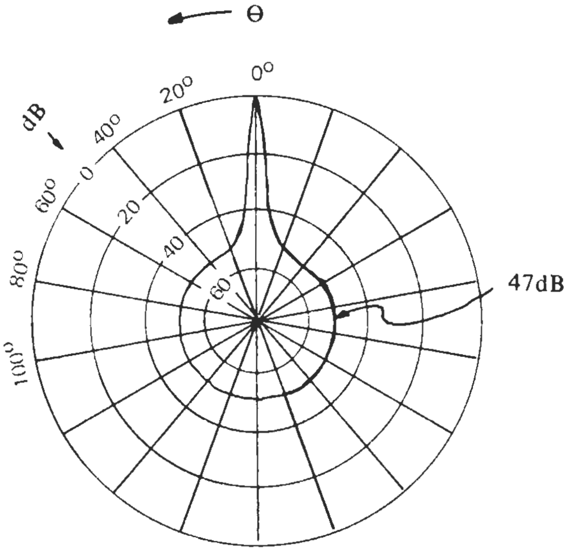


The figure at the left shows a typical plan view. The pattern may be studied in the other principal plane (vertical) by using the effective height in place of "d"

RADIATION PATTERN FOR EXAMPLE NO. 4
16 feet x 24 feet Rhombic Passive Repeater, Horizontal Cut
f = 6.175 GH_z, $2\alpha = 120^{\circ}$



PATTERN ENVELOPE
EXAMPLE NO. 4



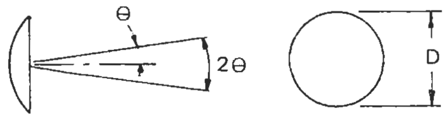
PATTERN ENVELOPE
EXAMPLE NO. 4

DETERMINATION OF 3dB AND 10 dB POINTS FOR VARIOUS MICROWAVE REFLECTORS

(Values calculated are typical, not a standard for specific manufactured devices)

λ = Wavelength = $0.9836/F_{GHz}$ in feet or $30/F_{GHz}$ in centimeters

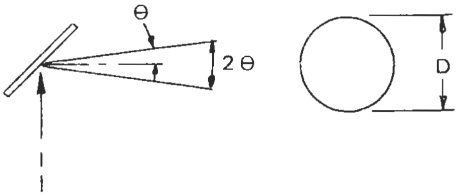
A. Parabolic reflector, circular aperture (typical for many microwave antennas)



Half power beam width $2\Theta_{HP} = \frac{70\lambda}{D}$

10 dB point for deflection angle allowable, $\Theta = \frac{60\lambda}{D}$

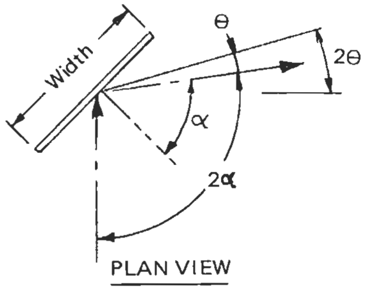
B. Flat - face reflector, circular aperture (typical for elliptical reflectors in periscope systems)



Half - power beam width, $2\Theta_{HP} = \frac{59\lambda}{D}$

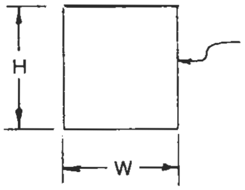
10 dB point for deflection angle allowable, $\Theta = \frac{50\lambda}{D}$

C. Flat - face reflector, rectangular or square aperture (typical for passive repeaters)



Half - Power beam width, $2\Theta_{HP} = \frac{51\lambda}{W \text{ or } H}$

10 dB point for deflection angle allowable, $\Theta = \frac{44\lambda}{W \text{ or } H}$



View along path of wave propagation

W = (width) (COSα)

Note:
For the rotation of a flat - face reflector about its center an angle, δ, the deflected beam angle, Θ may vary from δ to 2δ in accordance with the reflector system geometry (path angles and reflector orientation with reflector center as a reference).

CONCLUSIONS

The methods described for making the calculations for patterns and plots of patterns are useful to adopt as a uniform way of describing passive repeater radiation patterns and pattern envelopes. The information can be used to evaluate alignment procedures, structural rigidity requirements, angle-of-arrival effects on performance, and potential interference problems.

Admittedly some refinement should evolve with use of the methods. Some conditions could be more completely described with use of complex mathematical relationships and special solutions by computer applications. Tests may be made to improve the approximations for pattern envelopes and near-field patterns.

When the envelopes are used for interference investigations judgments should be made to evaluate the probable accuracies of the envelopes compared to the over-all methods and assumptions used for the interference studies.

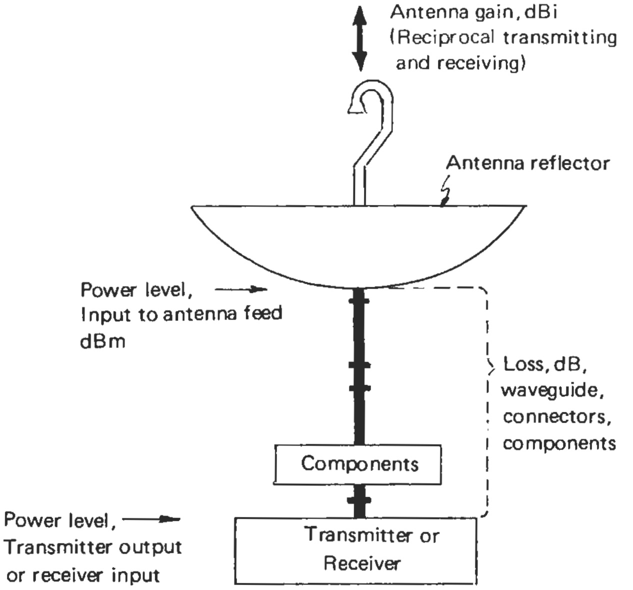
Some interference studies utilize a "standard" pattern envelope for all passives irrespective of shape, aperture size, and frequency. The general pattern envelope is assumed to be conservative. If a potential interference problem is displayed, the engineer is required to make a more detailed study of the situation. The methods described in this writing may be viewed as an improvement over the use of one general pattern envelope because the relationships for aperture size, aperture shapes, and carrier frequencies are maintained.

CHAPTER IV

NOTES ON MICROWAVE INTERFERENCE INVESTIGATIONS ON SYSTEMS UTILIZING PASSIVE REPEATERS

The following notes were developed to illustrate the use of the radiation patterns described in Chapter III and to guide the engineer making interference investigations in areas with passive repeaters. The figures and notes are considered to be self-explanatory.

TYPICAL MICROWAVE ANTENNA SYSTEM



DETERMINATION OF POWER LEVELS

Power Level at Transmitting Antenna Feed

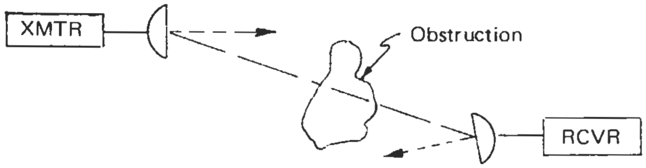
Transmitter power output level = (+__________ dBm)
Waveguide & component loss = (- __________ dB)

Power level, antenna feed = (+ __________ dBm)

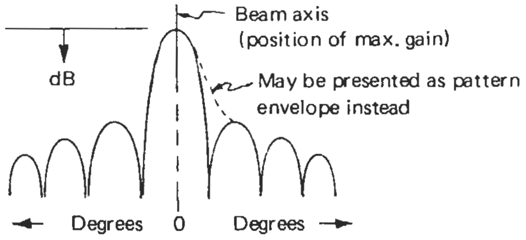
Power Level at Distant Receiver

Transmitter power output level = (+__________ dBm)
Waveguide & component loss, XMTR= (- __________ dB)
Transmitting antenna gain = (+__________ dBi)
Transmitting antenna discrimination = (-__________ dB)
Free space loss = (- __________ dBi)
Obstruction loss = (- __________ dB)
Receiving antenna gain = (+ __________ dBi)
Receiving antenna discrimination = (- __________ dB)
Waveguide & component loss, RCVR = (- __________ dB)

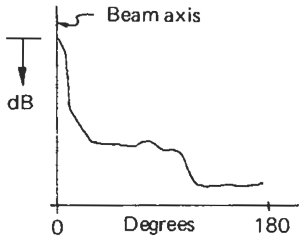
Receiver Input Level = (- __________ dBm)



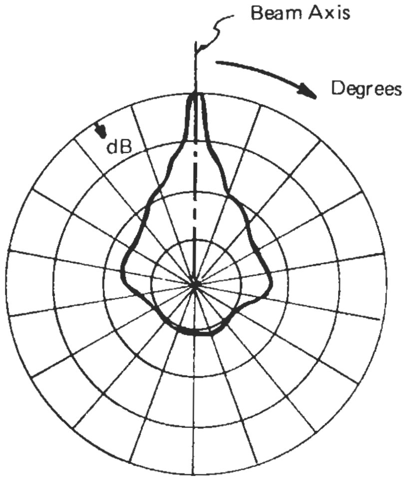
TYPICAL GRAPHICAL REPRESENTATIONS ANTENNA RADIATION (DISCRIMINATION)



Rectangular Decibel Plot of Pattern for Principal Plane, Near the Beam Axis

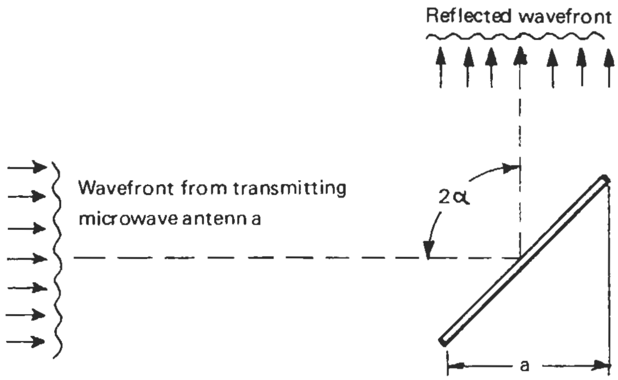


Rectangular Decibel Plot of Pattern Envelope for Principal Plane, 0° to 180° From Beam Axis



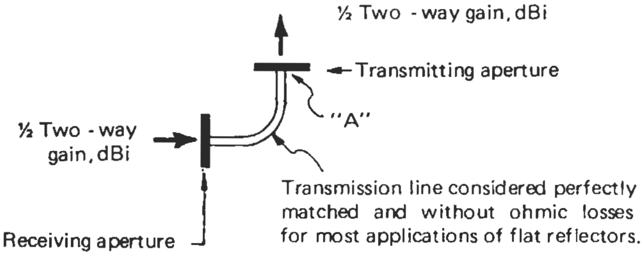
Polar Decibel Plot of Pattern Envelope for Principal Plane, 0° to 360°

PASSIVE REPEATER



"a" = Effective dimension = (length) (COS α)

PASSIVE REPEATER EQUIVALENT

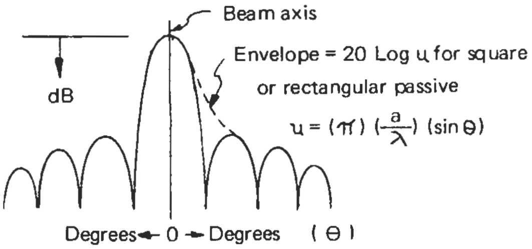


Transmitter power output level = (+ __________ dBm)
Waveguide & component loss, XMTR = (- __________ dB)
Transmitting antenna gain = (+ __________ dBi)
Transmitting antenna discrimination= (- __________ dB)
Free space loss = (- __________ dBi)
Obstruction loss = (- __________ dB)
½ passive repeater gain = (+ __________ dBi)

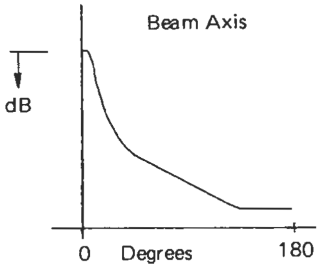
*Equivalent power level, point "A" = (__________)

*Power received from microwave transmitting antenna in the "far-field" of the passive repeater.

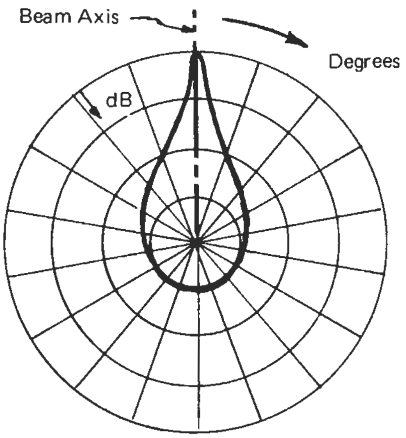
TYPICAL GRAPHICAL REPRESENTATIONS
PASSIVE REPEATER RADIATION (DISCRIMINATION)



Rectangular Decibel Plot of Pattern for Principal Plane, Near the Beam Axis

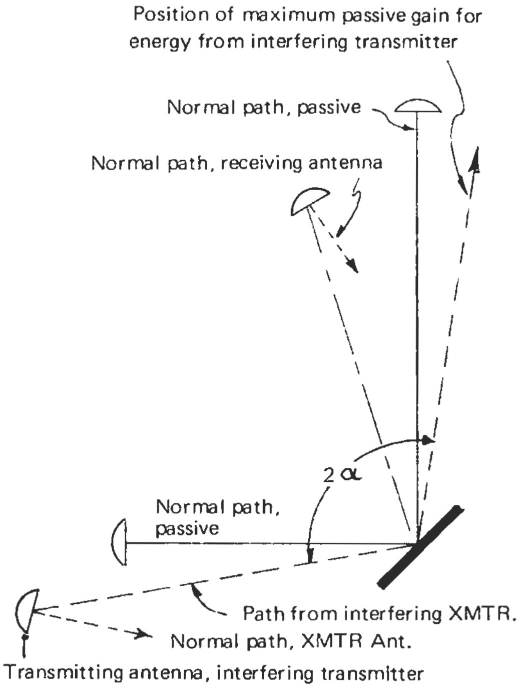


Rectangular Decibel Plot of Pattern Envelope for Principal Plane, 0° to 180° From Beam Axis (Calculated)

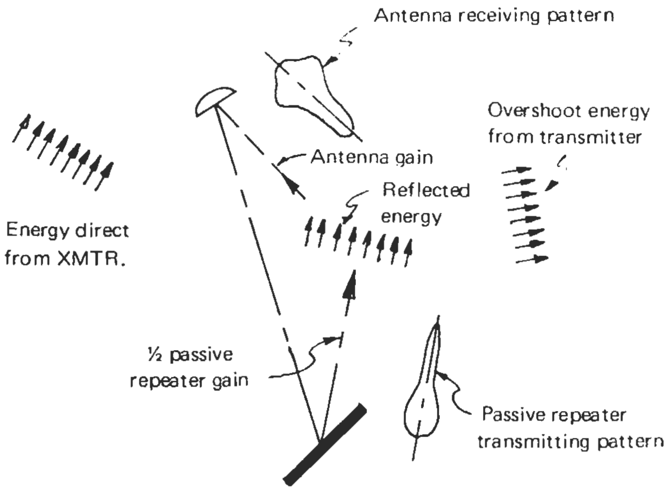


Polar Decibel Plot of Pattern Envelope for Principal Plane, 0° to 360° (Calculated)

POWER LEVEL AT MICROWAVE RECEIVER WHERE INTERFERENCE EVALUATION IS REQUIRED FOR POWER REFLECTED FROM A PASSIVE REPEATER



General Plan of a System with a Potential Interfering Signal Thru a Passive Repeater



Equivalent for Interfering Transmitter & Passive Repeater

Transmitter power output level = (+ ________ dBm)
Waveguide & component loss, XMTR = (– ________ dB)
Transmitting antenna gain = (+ ________ dBi)
Transmitting antenna discrimination = (– ________ dB)
Free space loss, XMTR to passive = (– ________ dBi)
Obstruction loss, XMTR to passive = (– ________ dB)
½ passive repeater gain = (+ ________ dBi)

Sub total
Algebraic sum

Equivalent power level at passive repeater site with ½ passive gain and transmitting pattern = (________ dBm)

½ passive repeater gain = (+ ________ dBi)
Passive repeater discrimination = (– ________ dB)
Free space loss passive to receiver = (– ________ dBi)
Obstruction loss, passive to rcvr. = (– ________ dB)
Receiving antenna gain = (+ ________ dBi)
Receiving antenna discrimination = (– ________ dB)
Waveguide & component loss, receiver = (– ________ dB)

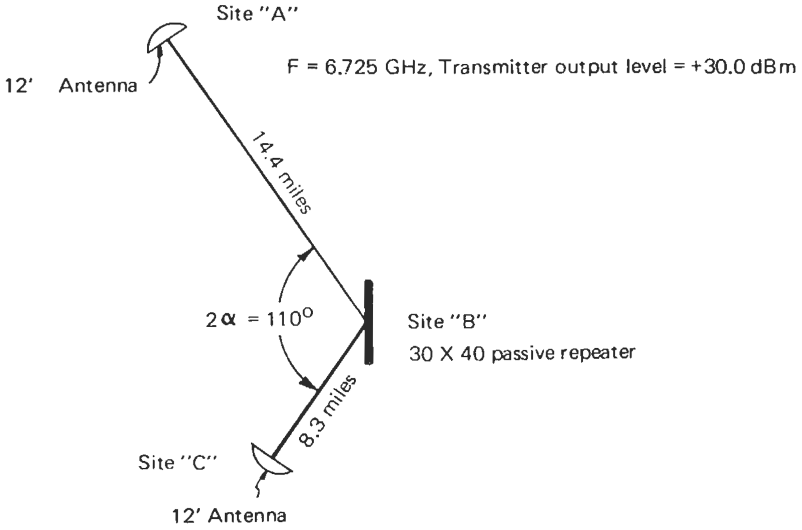
Input Power Level at Receiver = (– ________ dBm)

Note: The passive repeater gain is the two - way gain based on the horizontal angle, 2α, between the interfering transmitter path and the maximum gain position for reflection of the interfering signal (angle of incidence = angle of reflection).

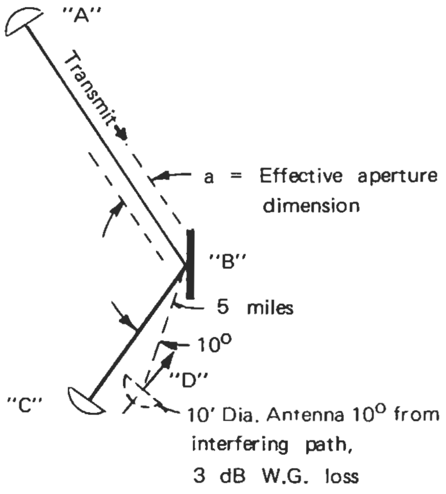
Discrimination figures in dB for the antennas and passive repeater typically are taken from a radiation pattern envelope for a principal plane positioned horizontally. Thus the possible discrimination for vertical angles is not usually included in the discrimination figure.

Example No. 1
INTERFERENCE INVESTIGATION

Site where concern for interference thru passive from site "A" transmitter is 10° from path azimuth to site "C" and 5 miles from the passive.



PLAN OF EXAMPLE SYSTEM
See Chapter II, page 27



Transmitter output level = (+ 30.0 dBm)
Waveguide & component loss, XMTR = (-3.0dB)
Transmitting antenna gain = (+45.6 dBi)
Transmitting antenna discrimination = (-0.0)
Free space loss, XMTR to passive = (-136.4 dBi)
Obstruction loss, XMTR to passive = (-0.0)
½ passive repeater gain = (+ 56.0 dBi)

Equivalent power level, passive site with ½ passive gain = (-7.8 dBm)

½ passive repeater gain = (+56.0 dBi)
Passive repeater discrimination = (-38.6 dB)
Free space loss, passive to receiver = (-127.1 dBi)
Obstruction loss, passive to receiver = (0.0)
Receiving antenna gain = (+ 44.0 dBi)
Receiving antenna discrimination = (-35.0 dB)
Waveguide & component loss, receiver = (-3.0 dB)

Input power level, received at "D" = (-111.5 dBm)

Note: It is likely the interfering power level at "D" would be lower than -111dBm by several dB due to more discrimination from vertical angles and possible obstructions between the passive and "D".

Calculation of Passive Repeater Discrimination

$u = \pi \left(\frac{a}{\lambda}\right) (\sin\Theta)$

Discrimination = 20 Log u

$a = (L)(\cos\alpha) = (40)(\cos 55^\circ) = 22.9$ feet.

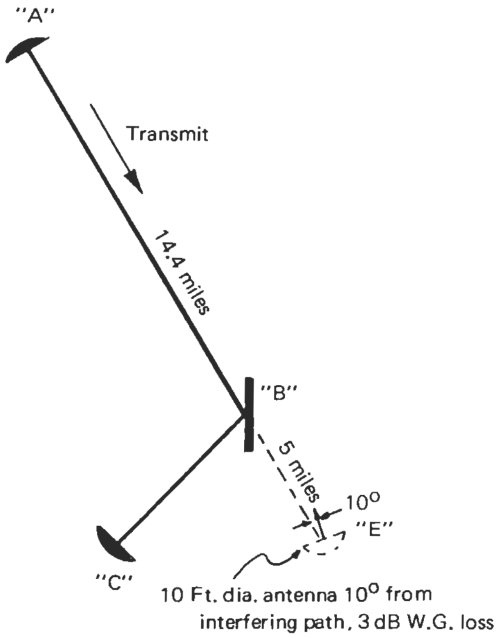
λ = Wavelength = 0.9836/6.725 = 0.146 feet.

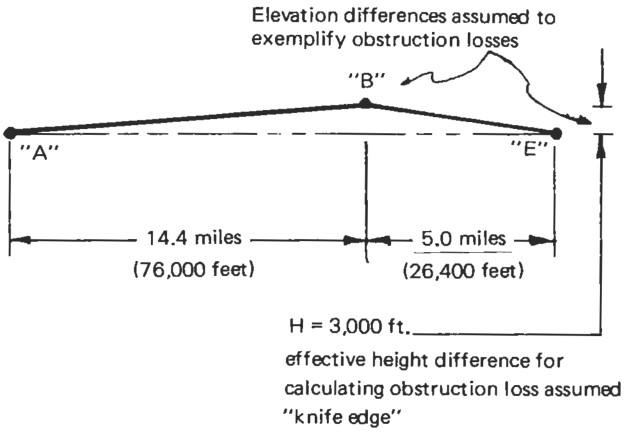
$u = (\pi)\left(\frac{22.9}{0.146}\right)(\sin 10^\circ) = 85.7$

20 Log u = 20 Log 85.7 = 38.6

EXAMPLE No. 2
INTERFERENCE INVESTIGATION

Site where concern for interference thru passive from Site "A" transmitter is on azimuth from "A" to "B" and 5 miles from the passive repeater.





Transmitter output level =	(+ 30.0 dBm)
Waveguide & component loss, XMTR =	(- 3.0 dB)
Transmitting antenna gain =	(+ 45.6 dBi)
Transmitting antenna discrimination =	(- 0.0)
Free space loss, XMTR to passive =	(- 136.4 dBi)
Obstruction loss, XMTR to passive =	(- 0.0)
Passive repeater gain =	(+ 112.0 dBi)
Passive repeater discrimination =	(−56.0dB)
Free space loss, passive to receiver =	(- 127.1 dBi)
Obstruction loss, passive to receiver =	(0.0)
Receiving antenna gain =	(+ 44.0 dBI)
Receiving antenna discrimination =	(- 35.0 dB)
Waveguide & component loss, receiver =	(- 3.0 dB)

Input power level, received at "E" = −128.9dBm

Calculation of Knife Edge Diffraction Loss "A" to "E"

$$\text{1st Fresnel zone radius at "B"} = \sqrt{\frac{\lambda\, d_1 d_2}{d_1 + d_2}}$$

$$= \sqrt{\frac{(0.146)(76{,}000)(26{,}400)}{102{,}400}}$$

1st Fresnel zone radius at "B" = 54 feet $= r_1$

$$\text{Knife edge loss} \approx 20\ \text{Log}\ \frac{2\pi H}{r_1}$$

$$\text{Knife edge loss} = 20\ \text{Log}\ \frac{(2)\ (\pi)\ (3{,}000)}{54} = 51\ \text{dB}$$

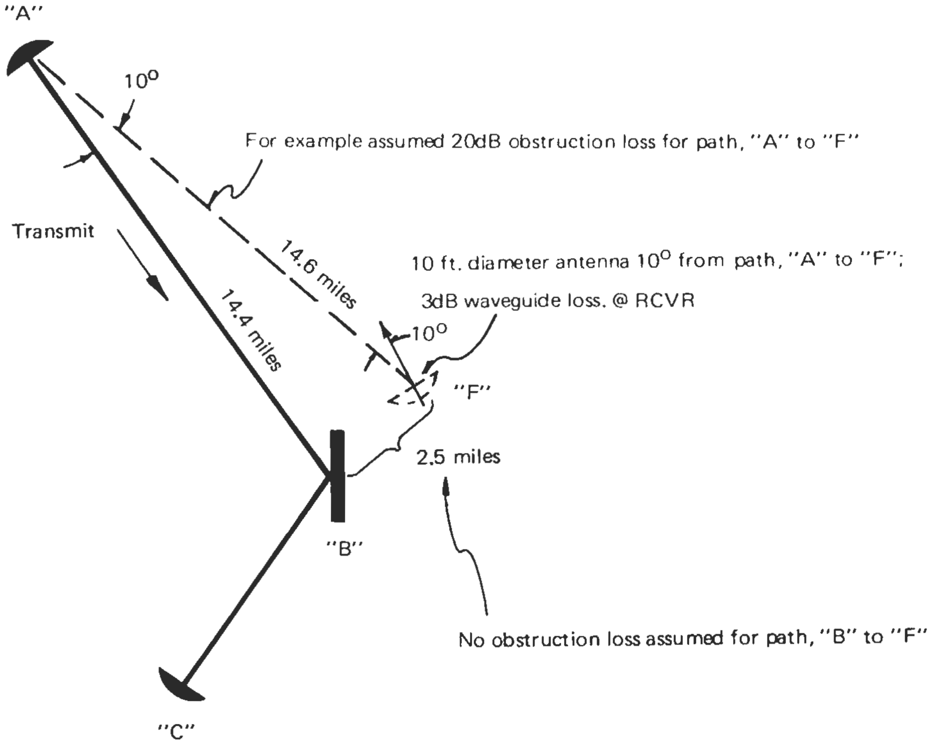
Compare with power directly from transmitting antenna at "A"

+ 30.0 dBm	- 3.0 dB	+ 45.6 dBi	- 138.9 dB	- 51 dB	+ 44.0 dBi	- 35.0 dB	- 3.0 dB	= - 111.3 dBm
XMTR "A"	W.G.	Ant. Gain	F.S.L. 19.4 miles	Obstruction Loss	Ant. Gain	Ant. Discr.	W.G.	Input power level, RCVR "E"

EXAMPLE No. 3
INTERFERENCE INVESTIGATION

Site where concern for interference thru passive from site "A" transmitter is 10° from azimuth "A" to "B", 14.6 miles from "A" and 2.5 miles from passive.

(Require interference power level at receiver site "F", XMTR at "A")



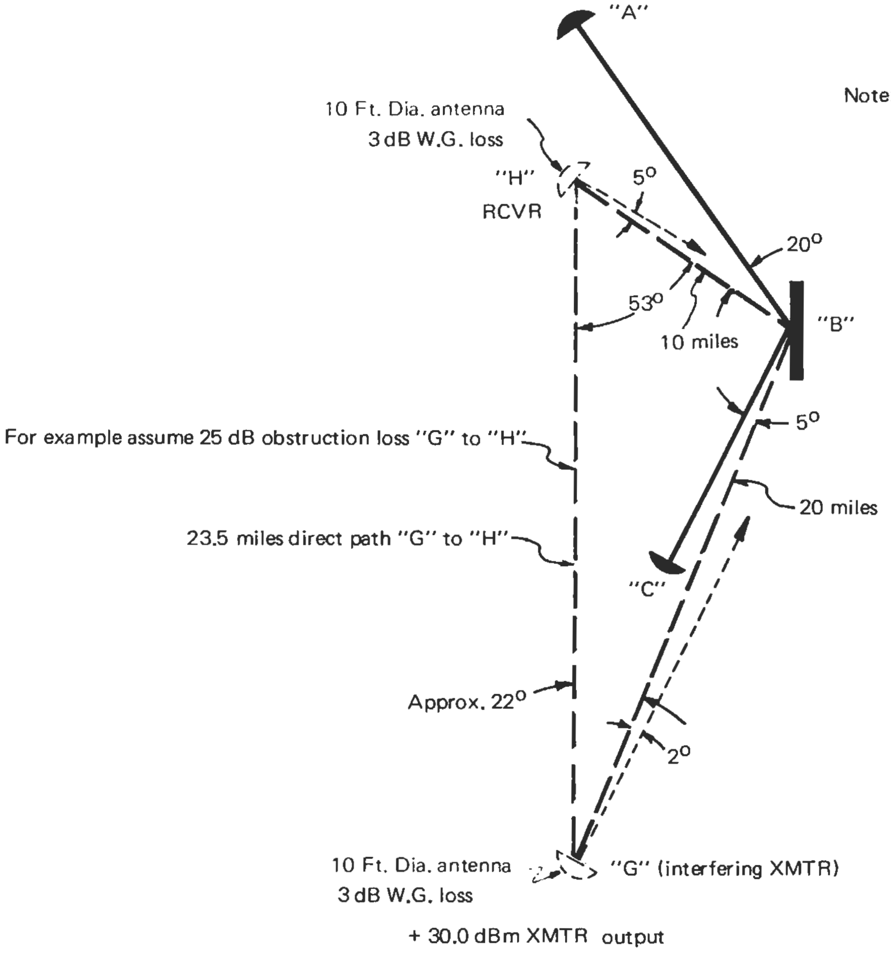
Transmitter output level =	(+ 30.0 dBm)
Waveguide & component loss, XMTR =	(- 3.0 dB)
Transmitting antenna gain =	(+ 45.6 dB)
Transmitting antenna discrimination =	(- 0.0)
Free space loss, XMTR to passive =	(- 136.4 dBi)
Obstruction loss, XMTR to passive =	(- 0.0)
Passive repeater gain =	(+ 112.0 dBi)
Passive repeater discrimination =	(- 56. dB)
Free space loss to receiver =	(- 121.1 dBi)
Obstruction loss, passive to receiver =	(0.0)
Receiving antenna gain =	(+ 44.0 dBi)
Receiving antenna discrimination =	(- 50. dBi)
Waveguide & component loss, receiver =	(- 3.0 dB)
Input power level, received at "F" =	(–137.9dBm)

Compare with power directly from transmitting antenna at "A"

+ 30.0 dBm	- 3.0 dB	+ 45.6 dBi	– 38.0 dB	– 136.5 dBi	– 20.0 dB	+ 44.0 dBI	- 35.0 dB	– 3.0 dB =	–115.9 dBm
XMTR "A"	W.G.	Ant. Gain	Ant. Discr.	F.S.L.	Obstruction Loss	Ant. Gain.	Ant. Discr.	W.G.	

EXAMPLE No. 4
INTERFERENCE INVESTIGATION

Concern for interference at site "H" receiver from site "G" transmitter; assumed obstruction loss "B" to "H" = 6dB



For example assume 25 dB obstruction loss "G" to "H"

23.5 miles direct path "G" to "H"

Note: 2α for normal system = 110°; gain of passive for interference from site "G" based on 2α of 120°.

Transmitter output level = (+ 30.0 dBm)
Waveguide & component loss, XMTR = (- 3.0 dB)
Transmitting antenna gain = (+ 44.0 dBi)
Transmitting antenna discrimination = (- 21.0 dB)
Free space loss, XMTR to passive = (- 139.2 dB)
Obstruction loss, XMTR to passive = (0.0)
Passive repeater gain = (+ 110.9 dBi)
Passive repeater discrimination = (-43.0dB)
Free space loss, passive to receiver= (- 133.2 dBi)
Obstruction loss, passive to receiver = (- 6.0 dB)
Receiving antenna gain = (+44.0dBi)
Receiving antenna discrimination = (- 24.0 dB)
Waveguide & component loss, receiver = (- 3.0 dB)

Input power level, received at "H" = (-143.5dBm)

Compare with power directly from "G" to "H"

XMTR "G"	W.G.	Ant. Gain	Ant. Discr.	F.S.L.	Obstruction Loss	Ant. Gain	Ant. Discr.	W.G.	Input power level, RCVR "H"
+ 30.0 dBm	- 3.0 dB	+ 44.0 dBi	- 38. dB	- 140.6 dB	-25.0 dB	+ 44.0 dBi	- 47 dB	- 3.0 dB =	- 138.6 dBm

INTERMODULATION NOISE CONSIDERATIONS WHERE PASSIVE REPEATERS ARE EMPLOYED

(Wide Band Communications Applications)

The portion of the chart for gains on page 35 shown as "Zone A" indicates that there can be some intermodulation noise problems at lower microwave frequencies with the small passive repeaters. This problem has been reported to Microflect only in a few instances over the many years of selling passive repeaters and the hundreds of installations involved. The loading capability of most systems has not been intended for more than 1200 voice channels, but a few have been intended to allow a traffic capability of 1800 channel design. Whether passive repeaters are used or not, a precise quantitative evaluation of intermodulation noise levels is not practical to undertake. However, when passive repeaters are applied the following comments and guidelines may be used to establish some quantitative criteria for the system design with respect to intermodulation noise.

(1) Passive repeaters are linear devices and they do not introduce any significant noise to the system in their most practical form of construction. (Intermodulation noise is most often caused by non - linear components in the microwave system.)

(2) A significant level of discrimination between the passive reflected signal and energy from other reflecting objects illuminated by the direct radiator can be maintained by applying a passive repeater with an effective area large compared to the "effective area" of other reflecting bodies. For many objects this level could be compared in decibels and used as part of the quantitative system evaluations. (Keep in mind the possible lower level of energy received by the other reflecting bodies and their low aperture efficiencies.)

(3) The application of microwave antennas with narrow beam widths will cause many of the undesired reflecting objects to be illuminated with a much lower level of energy. This may also allow the possibility of "notching out" one significant reflection point.

With the use of the above guidelines and the notes on interference displayed in this chapter the problem of intermodulation noise could be treated as an interference type problem.

OVERSHOOT – DOUBLE PASSIVES

Also it is worth while to note the possibility of "over-shoot" energy for double passive configurations with very small transfer angles. This also should be treated as an interference - type problem making certain that appropriate diffraction losses are accounted in the problem for the terrain features on the total path. This problem can occur with the use of the configuration shown as Fig. 2-1 on page 38 where ψ is only a few degrees and the obstruction losses for the direct path are small thru the expected range of refractive index changes.

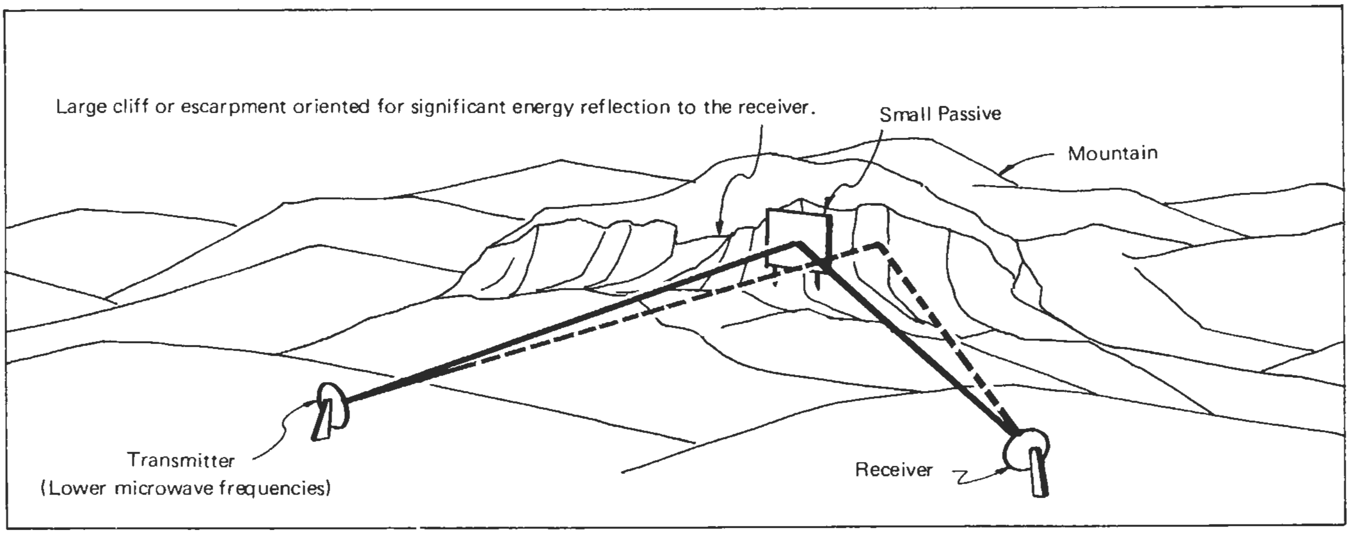


Figure 4-1
Illustration of terrain features that may cause intermodulation noise problems at the lower microwave frequencies

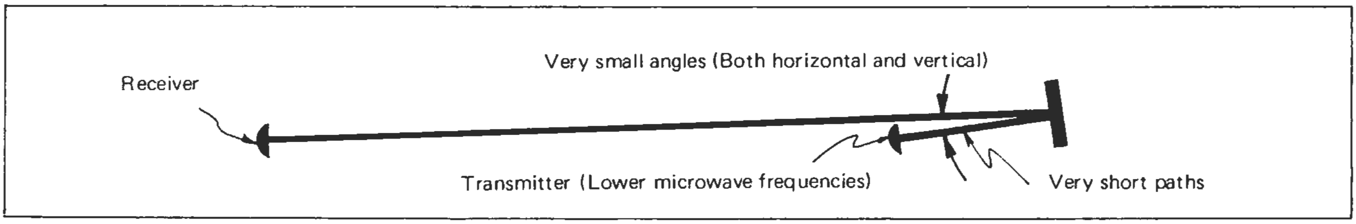


Figure 4-2
Illustration where return loss should be evaluated for energy returning from the passive to the transmitter.

CHAPTER V

SPACE DIVERSITY ON MICROWAVE SYSTEMS USING PASSIVE REPEATERS

INTRODUCTION

In the past frequency diversity techniques have been preferred over space diversity techniques for overcoming multipath fading often encountered on microwave communcations systems. However, a frequency diversity scheme requires twice as much frequency spectrum as the near equivalent space diversity scheme. This principal disadvantage of frequency diversity requires the application of space diversity as a worthwhile alternative for obtaining the required system reliability during conditions of deep fading from multipath propagation.

Two types of multipath problems are usually considered: (1) multipaths from specific reflection points, and (2) atmospheric multipaths (secondary path generation due to meteorological layering). A space diversity scheme typically employs one antenna at the transmitting end of a path and two antennas, spaced vertically, at the receiving end. This type of antenna arrangement is typical whether either one or both of the sources of multipath fading can occur. For a secondary path from a specific reflection point a good approximation of the required antenna spacing can be calculated directly from the geometry of the system. However, one cannot make a geometric analysis for optimum spacing of antennas where atmospheric multipaths are considered the source of the fades.

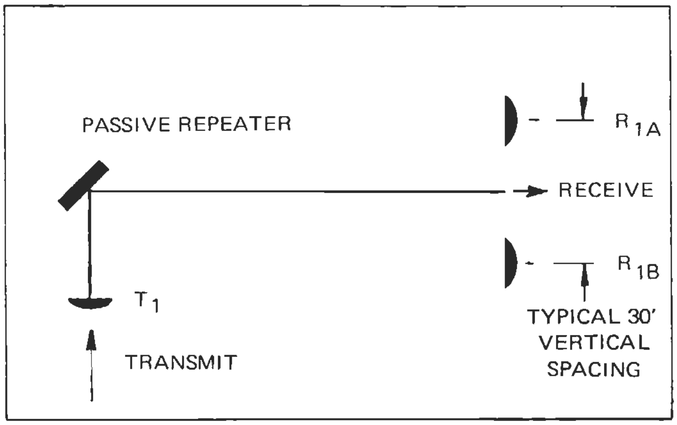
As the conventional space diversity system has two apertures on the receiving end of a path, it is logical for one to question the effects of having a passive repeater on the system between a transmitter and receiver. In effect the passive repeater is both a transmitter and a receiver as it re - directs the energy it receives.

A hasty conclusion might be that two passive repeaters (in place of a single passive) are always required for space diversity schemes. This reasoning is consistent with the usual conception of the diversity operation unless one considers a phenomenon that might be described as "aperture diversity". Briefly, the mechanism of aperture diversity can be visualized by considering that the vertical dimension of the passive may be large with respect to the interference pattern over the passive face. The result is that a large passive repeater or antenna integrates* the received power over a significant portion of the interference pattern.

*Note: This is not to imply that the passive has any combining effect on the energy. The passive is a linear device and will reflect (transmit) the energy in the form received without changing the amplitude and phase as seen by the electronic receiving equipment.

GENERAL CONFIGURATIONS OF SYSTEMS EMPLOYING SPACE DIVERSITY TECHNIQUES WITH PASSIVE REPEATERS

The following configurations with their associated qualifications and notes exemplify the possible uses of passive repeaters on systems employing space diversity techniques. These general examples should not be interpreted as the only situations applicable to passive repeaters, but they can be used as guidelines for judging other specific system configurations.

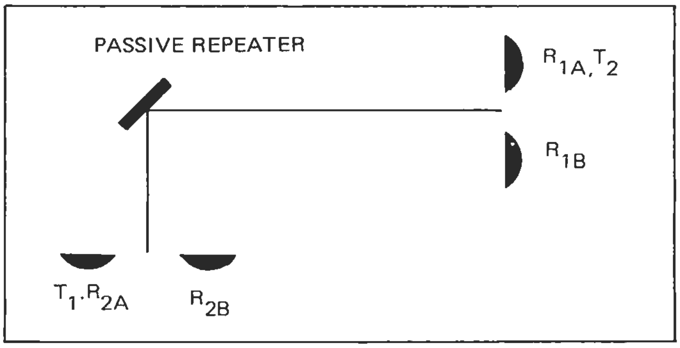


ONE—WAY TRANSMISSION

The methods of determining transmission reliability are applicable for space diversity applications with the following qualifications:

a. The system has one - way transmission only.

b. The passive repeater is in the near - field of the antenna or close enough so that reflection points or atmospheric multipath fading, on the short path, do not significantly decrease the system reliability.



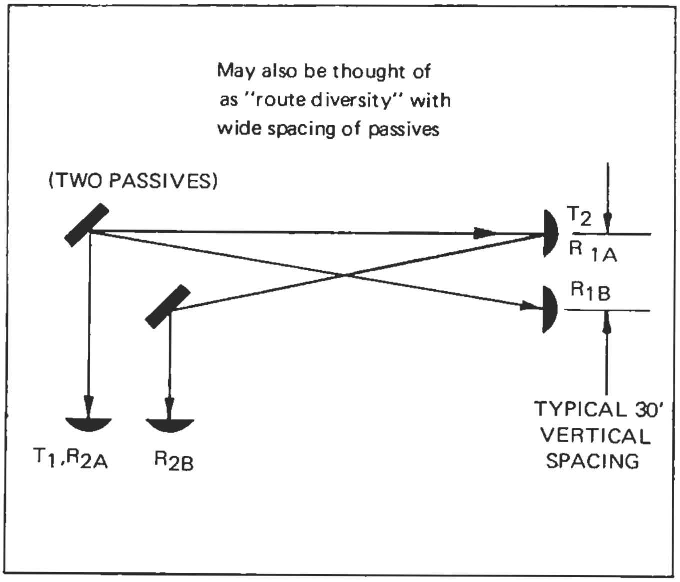
TWO - WAY TRANSMISSION

The methods of determining transmission reliability are applicable for space diversity applications with the following qualification:

The vertical dimension of the passive repeater must be large (for many microwave carrier frequencies 20 feet or more). The result at the passive location is a phenomena that might be described as aperture diversity; that is, the passive repeater aperture is large enough to act as though space diversity of smaller apertures were applied.

Note: The effects of aperture diversity improve as the vertical dimension of the aperture gets larger. Sizes may be limited in the vertical direction by refractive index changes and their probability distributions in time. In general, the closer the reflection point is to the passive, the smaller the fresnel interference pattern is across the face. A high—low reflection path with the passive at the low end would result in such a pattern.

For concept of aperture diversity introduced by test results refer to "Path Loss Testing of the Trans–Canada TD–2 Route", W.Von Hagen, A.N. MacDiarmid, and L.V. Goldenberg, I.R.E. Convention Paper 49 presented at Toronto Canada, October 16–18, 1957. For calculation of space diversity improvement refer to: "Space Diversity on a 6 GHz Path with a Billboard Reflector", A. Vigants, Bell Telephone Laboratories, Holmdel, New Jersey.



TWO–WAY TRANSMISSION

The methods of determining transmission reliability are applicable for space diversity applications with the following qualifications:

a. Compensation for different arrival time of signals must be made by a phase - delay network in the diversity combiner scheme.

b. The passive repeaters must be spaced as far apart as practical to lessen the possibility of reflections from one affecting the other path, and/or

c. One path from the antennas to the passives should be as short as possible so that the antennas and passives are close - coupled (1/k less than 2.0 if possible.)

The foregoing example configurations may be expanded to apply to other situations. For example, a double passive installation may be used in place of the single passive shown. Aperture diversity applies to large apertures in general. Therefore, one large antenna may be considered in place of two smaller ones for some space diversity applications. Although, the antennas used on typical microwave systems (6 feet diameter to 12 feet diameter), usually are not large enough.

ANTENNA SPACING FOR SPACE DIVERSITY CONFIGURATIONS

The antenna spacing for reflection points may be determined from Figure 5-1 and the associated formula:

$$S = \frac{(1.3)\,(D)\,(10^6)}{(f)\,(h)}$$

Where:

D = total path distance in miles
f = frequency in MHz
h = height in feet of the transmitting antenna above the tangential plane
S = spacing between antenna centers in feet

It was pointed out that it is not possible to make a geometric analysis of the paths involved due to atmospheric multipath type fading condition. However, the following formula presented in C.C.I.R. Report No. 376 (Oslo 1966) is used by some for comparison of calculated spacings with those known to be successful by experience.

$$P_S = \exp\left[-0.0021\Delta h f\sqrt{0.4d}\right]$$

Where:

P_S = correlation factors (the optimum value is considered 0.6)
Δ h = vertical spacing between antennas in METERS
f = frequency in GH_z
d = path length in Km

The separations normally lie between 100 and 200 wavelengths. Experience has proven that acceptable diversity improvement will be obtained with spacing intervals of about 60' at $2GH_z$, 45' at $4GH_z$, 30' at $6GH_z$, and 15' to 20' at $11GH_z$.

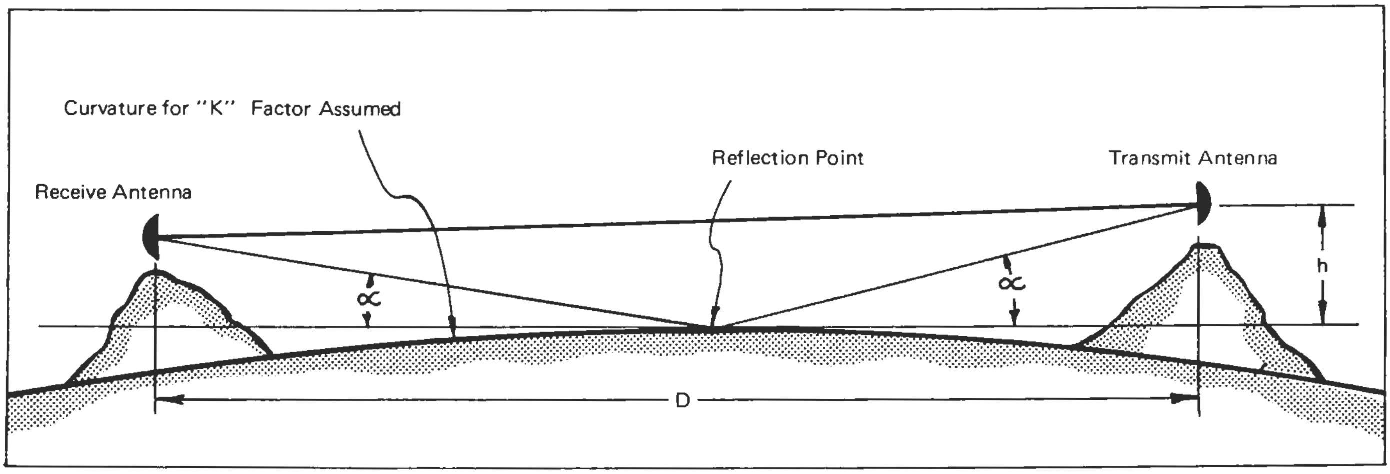


Figure 5-1

APERTURE DIVERSITY (Integration)

Sometimes the spacing at one or both ends of a path becomes relatively small or nearly equal to the dimensions of apertures that might be used. There is a reduction in fading due to multipaths caused by the aperture integrating the received signal power over a significant portion of the interference fringes. Thus, on systems employing spacing of apertures for diversity action, a single aperture may be adequate at some locations.

The following illustrations of Figure 5-2 graphically show the effects of aperture integration. The fading relative to free space is related to the ratio of the aperture vertical dimension to the vertical fringe pattern, A/F; where "F" is equal to two "S", "S" being the calculated spacing for two apertures spaced vertically.

EXAMPLE SYSTEM SPACING COMPUTATIONS AND CONSIDERATIONS

Assume the system depicted in Figure 5-3 is contemplated for operation as a space diversity system.

The following notes and computations illustrates some of the thoughts and methods used to confirm the possibility of obtaining good diversity action on the paths shown in Figure 5-3

Upon examination of the system it could be judged that atmospheric multipaths are not a likely problem at 6 GH_z on the 9.5 mile path (optimistic for many climates).

A single large antenna with the large passives may offer the advantages of "aperture diversity" on the shorter path. Often the differences in antenna sizes at each end are chosen for system gain requirements, and the location of the large antenna is chosen for physical reasons. In this instance there may be a distinct advantage to place the larger antenna on the shorter path.

With a probable reflection point out from the passives on the short path (the passive being considered the transmitter end), and the passives being 400 feet above the tangential plane, the vertical spacing required for two antennas would be calculated in the following manner:

$$S = \frac{(1.3)(D)(10^6)}{(f)(h)} = \frac{(1.3)(9.5)(10^6)}{(6,000)(400)} \approx 5.1 \text{ ft.}$$

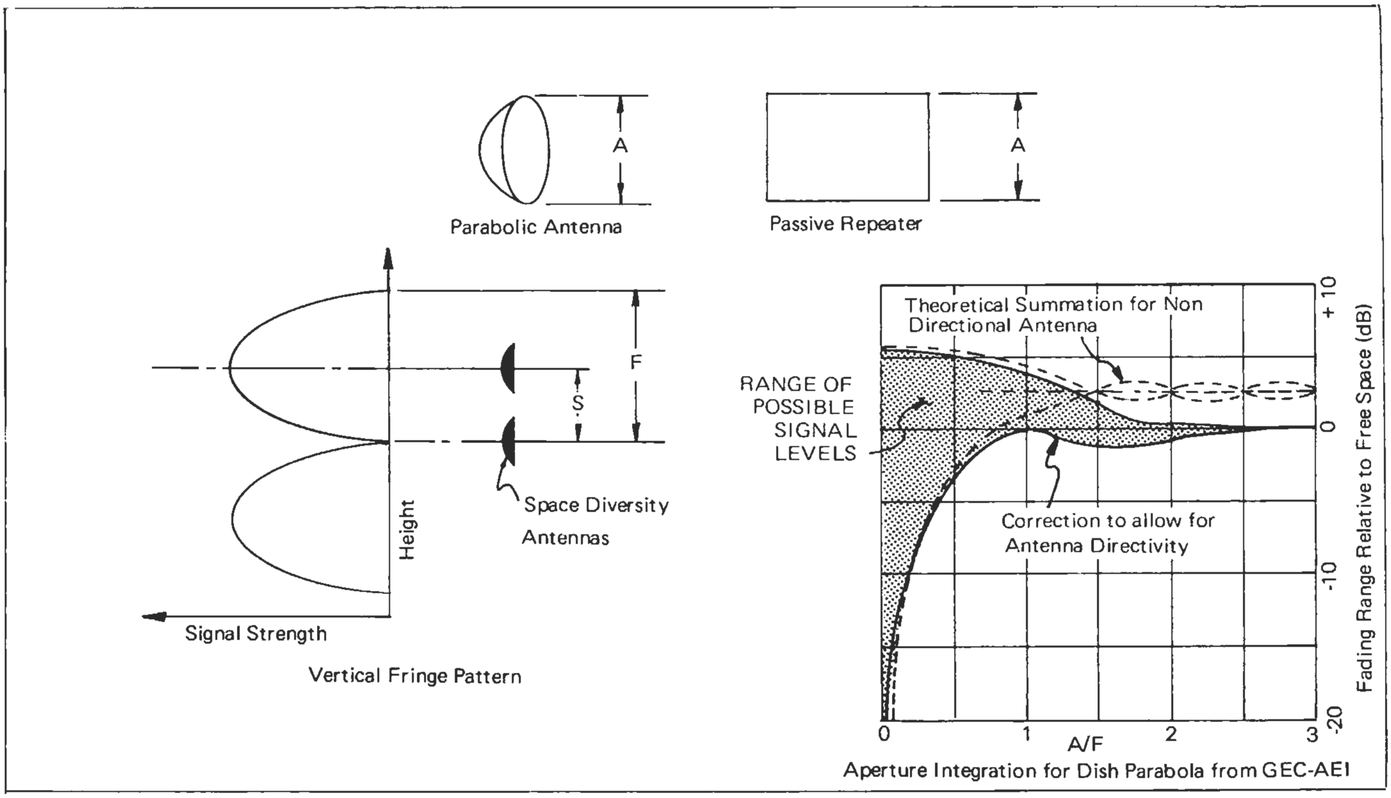


Figure 5-2

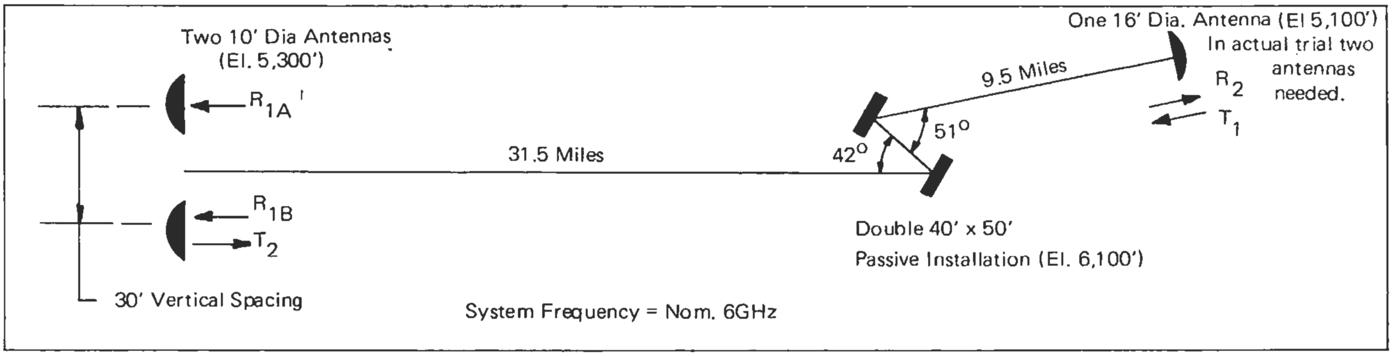


Figure 5-3

This spacing is small compared to the planned 16 ft. diameter aperture. Thus the prospects of aperture integration over the interference pattern occurring are favorable. The fringe spacing, "F", is two "S", or about 10 feet. The aperture to fringe ratio, A/F, is 16/10, or 1.6. In accordance with Figure 5-2 the diversity action for the single aperture should be good for the one reflection point of concern (not for atmospheric multipath).

Next, it is logical to conclude that the 40 ft. high passive is large enough for aperture integration for signals transmitted from the 16 ft. antenna. However, the adequacy of the passives should be investigated for transmission from the 10 ft. antenna to the passives over the 31.5 mile path.

Over this longer path the possibility of fading due to atmospheric multipaths should be considered. The spacing for this fading problem is estimated by using the semi-empirical formula introduced by C.C.I.R. with an assumed correlation factor of $P_S = 0.6$.

$$P_S = \exp\left[-0.0021 \Delta h f \sqrt{0.4d} \right] =$$

$$\exp\left[-(0.0021)(\Delta h)(6) \sqrt{(0.4)(31.5)(1.61)} \right]$$

$$\Delta h \approx 9 \text{ meters} \approx 30 \text{ feet}$$

The 40 ft. high passives should operate satisfactorily for aperture integration during atmospheric multipath conditions, and the 30 ft. spacing of the two 10 ft. antennas checks with this computation.

The final check of the system would be to check for points of reflection on the 31.5 mile path.

With a probable reflection point on the long path where the 10 ft. antenna transmits 200 ft. above the tangential plane the required aperture spacing (if two were used) at the passive site is determined in the following manner:

$$S = \frac{(1.3)\ (D)\ (10^6)}{(f)\ (h)} = \frac{(1.3)\ (31.5)\ (10^6)}{(6000)\ (200)} \approx 34 \text{ ft.}$$

$$F = 2S = 68 \text{ ft.};\ A/F = 40/68 \approx 0.6$$

Refer to Figure 5-2 for aperture integration. It is seen that the possible signal level below free space might be about 3dB down for A/F = 0.6. This exhibits good diversity action with the large passives on the longer path. If this same reflection point were assumed reversed; that is, transmission assumed from the passive site, the 30 ft. spacing of the 10 ft. antennas would be judged as adequate.

RELIABILITY CALCULATIONS

The space diversity improvement for the system operating through a passive may be approximated by the following:

$$\text{Improvement factor} = \frac{7.0 \times 10^{-5} \times F_{GHz} \times H^2 \times 10^{F/10}}{D}$$

F_{GHz} = Frequency in GH_z

H = Nominal height of reflector, feet

F = Fade margin, dB, for selected sizes of antennas, passives; power level of XMTR, etc.

D = Distance of longest path in miles.

The use of this method of calculating the space diversity improvement factor requires the reflector size be selected for a suitable fade margin, the unprotected fade probability be calculated, and the improvement needed to meet transmission objectives be determined. Then the improvement calculated is compared with the improvement desired.

CONCLUSIONS

Many microwave systems employing single passive repeaters (or the typical double passive installation) will perform satisfactorily for transmission reliabilities expected of space diversity schemes. In fact, many existing installations that were not specifically designed for diversity operation may be experiencing the benefits of space diversity through the size of the passive and configuration of the system. It is important to realize the conditions under which passives are compatible with space diversity schemes so that the full economic advantage of the passive repeater application can be assessed. (For over - water paths larger apertures have been proven advantageous over smaller apertures because the larger, narrow - beam aperture tends to discriminate against the water reflections.)

Finally, it should be recognized that some of the disadvantages of space diversity as compared to frequency diversity cannot be overcome by any configuration, size, arrangement of apertures, or by special electronic circuitry. In a very general form some of the possible disadvantages are listed for easy reference or recollection:

1. Equipment costs and complexity can be greater.
2. Maintenance without service interruption can be a problem.
3. Arrangement of protection channels is not as convenient.
4. Compensation for delays on wide - band systems may require special attention.
5. Passive repeaters will not always be a substitute for the conventional space diversity scheme using antennas only in combination with special electronic equipment, but in some cases a single large passive (or two for closely coupled double passives) may be all that is needed.

CHAPTER VI

EFFECTS OF "ANGLE OF ARRIVAL" ON PASSIVE REPEATER PERFORMANCE

REFRACTIVE INDEX CHANGES

For Line - of - Sight microwave systems obviously the earth's atmosphere is the transmission medium. The controlling factor is the vertical distribution of refractive index. The refractive index of the atmosphere varies with dielectric constants, which in turn depends upon pressure, temperature, and humidity. The "K" factor used for profiling microwave paths varies with the refractive index gradient.* Thus the microwave wave is slightly refracted or bent through the atmosphere in various amounts as atmospheric conditions change.

BEAM WIDTHS OF LARGE APERTURES MICROWAVE DEVICES

The beam widths of large - aperture microwave devices such as large reflectors become smaller as the frequency increases. Therefore a 30 foot high reflector on an $11 GH_Z$ system has a very narrow beam width that can cause the reflector to be responsive to atmospheric changes. The variances in bending of the wave front will cause the front to arrive at various angles to the reflector normal aperture. This "decoupling" of antennas and reflectors may cause a loss in signal that should be accounted in the design of the transmission system. The loss is most significant on very long paths with extremely narrow - beam apertures.

CALCULATING CHANGES IN ANGLE OF ARRIVAL FOR CHANGES IN "K" FACTORS

For situations where the refractive index may be approximated by a linear gradient, the factor "K" is calculated or assumed, and the angle of arrival change from K = ∞ to K = X will be:

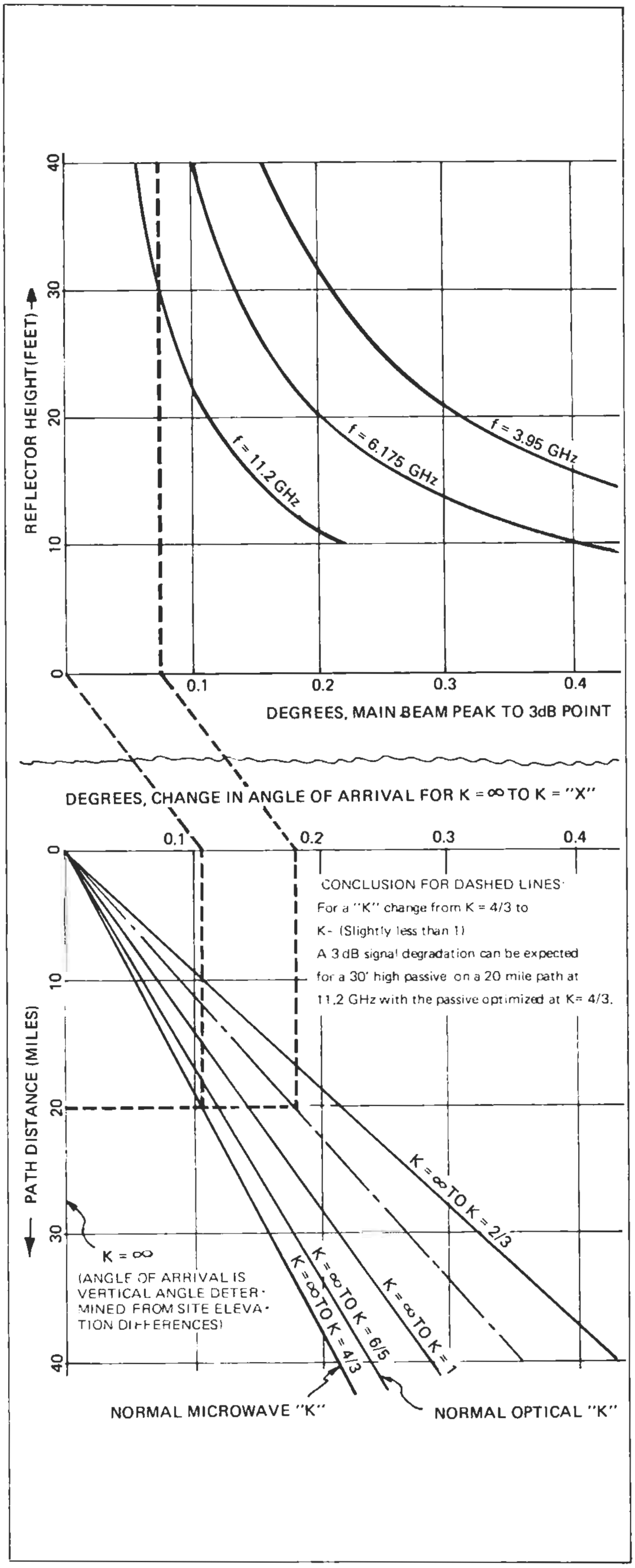
$$\Delta\Theta = \Theta_{(K=X)} - \Theta_{(K=\infty)} = \frac{-0.079D}{K} \quad \text{m rad}$$

$$\text{or} \approx \frac{-0.0045D}{K} \quad \text{Degrees}$$

Where D is the distance in kilometers and K is typically a factor of the order of magnitude of 4/3, 6/5, 7/6, 1, 2/3, 1/2.

K is 4/3 for "normal" propogation.

K is often chosen as 6/5 or 7/6 for optical sighting.



CONCLUSION FOR DASHED LINES:
For a "K" change from K = 4/3 to
K- (Slightly less than 1)
A 3 dB signal degradation can be expected
for a 30' high passive on a 20 mile path at
11.2 GHz with the passive optimized at K= 4/3.

Figure 6-1

$$* K = \frac{157}{157 + \frac{dN}{dh}}$$

$\frac{dN}{dh}$ is gradient in N units per kilometer

N = radio refractivity

RECOMMENDATIONS FOR GAIN CALCULATIONS, FADE MARGINS, AND LIMITING VERTICAL DIMENSIONS OF PASSIVE REPEATERS

It is not recommended that angle of arrival changes be represented in the determination of the passive repeater gain. It may be desireable, however, to consider the possible effects of angle of arrival when selecting a fade margin.

The limiting vertical dimension of the passive repeater depends upon the expected "K" change, the system frequency, and the path distance. It is seldom that practical selections of passive repeaters will have the vertical dimension limited by refractive index changes. But an awareness of the potential problem is worth while. The graphs on page 64 relate path distances, "K" changes, system frequency, 3 dB points, and reflector heights. These graphs cannot be used to conclude a limiting height of reflector, but they may be used to assess an order of magnitude of the problem or definitely eliminate the problem from consideration. For example, the dashed lines on the graph show that a 3 dB fade may occur from possible refractive index changes for a 30 foot high reflector at 11.2 GHz for a 20 mile path (change in "K" from 4/3 to slightly less than K= 1).

CHAPTER VII

PASSIVE REPEATER BEARING, EFFECTIVE AREA, POLARIZATION SHIFT

Whenever, a microwave wave front encounters a smooth, flat, metallic, surface, such as a passive repeater, with the linear dimensions of the passive large with respect to the wavelength of radiation, specular reflection takes place. A main characteristic of this reflection, which also accounts for the imaging properties of mirrors, is a compliance with Snell's law for reflection; that is, the angles of incidence and reflection are equal and coplanar. Stated in another more specific manner the law involves the following two requirements:

(1) The incident ray, the reflected ray, and the normal to the reflecting surface all lie in the same plane.

(2) The incident and reflected rays make equal angles with the normal.

The following illustration shows the angles involved for the "radio mirror", the passive repeater.

The basic angles surveyed or calculated from coordinates and elevations are the horizontal included angle, 2α, and the vertical path angles, Θ_1, and Θ_2. The passive face is then oriented in accordance with the face angle, Θ_3, and the horizontal correction angle, $\Delta\alpha$. The angle "C" is measured in the plane of the incident and reflected beam axes, and it may be desireable to use this angle for determination of the effective area and possibly the polarization rotation.

The example calculation on page 66 illustrates a typical determination of Θ_3 and $\Delta\alpha$. The blank form on page 67 is intended to be used for other calculations, where the page is copied with an office copier.

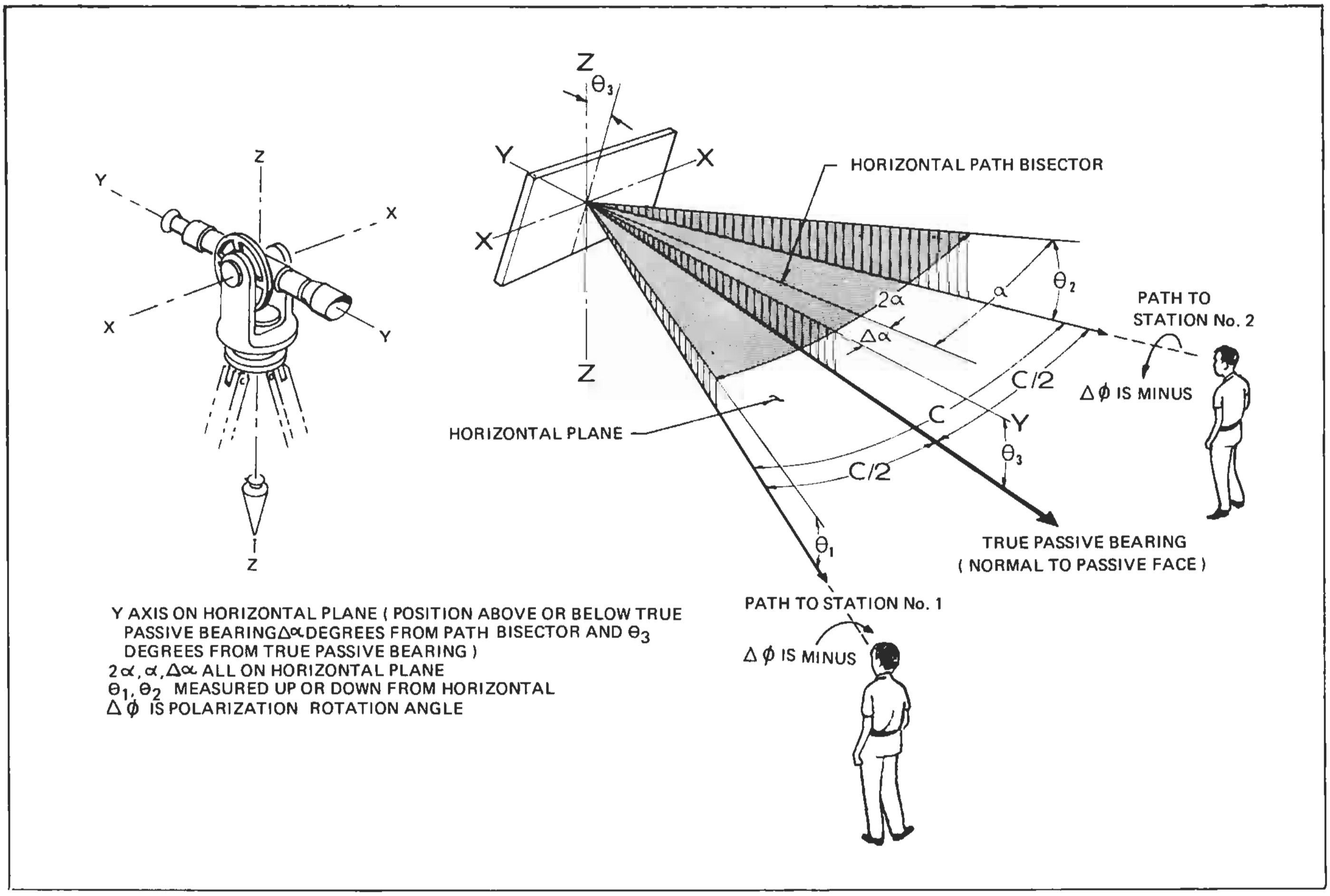


Figure 7-1

EXAMPLE COMPUTATIONS, FACE ANGLE & BEARING

PASSIVE REPEATER BEARING CALCULATION SHEET FOR Θ_3 AND $\Delta\alpha$

Passive Size 20'X 24'	Site WEST GLACIER PASSIVE REPEATER NO.1	Location NORTHWESTERN MONTANA NEAR WEST GLACIER

Horizontal included angle between paths: $2\alpha = 68.88$ degrees

One-half the horizontal included angle $\alpha = 34.44$ degrees

Smaller vertical path angle from horizontal: $\Theta_1 = 1.58$ degrees ☐ Up ☒ Down

Larger vertical path angle from horizontal: $\Theta_2 = 11.76$ degrees ☐ Up ☒ Down

$\cos\Theta_1$	$= 0.9996$	$\cos\Theta_1$	$= 0.9996$
$\cos\Theta_2$	$= 0.9790$	$\cos\Theta_2$	$= 0.9790$
$\cos\Theta_1 + \cos\Theta_2$	$= 1.9786$	$\cos\Theta_1 - \cos\Theta_2$	$= 0.0206$
$\sin\Theta_1$	$= +0.0276$	$\tan\alpha$	$= 0.6857$
$\sin\Theta_2$	$= +0.2038$	$\cos\alpha$	$= 0.8247$
$\sin\Theta_1 + \sin\Theta_2$	$= +0.2314$		

$$\tan\Delta\alpha = \tan\alpha\,\frac{\cos\Theta_1 - \cos\Theta_2}{\cos\Theta_1 + \cos\Theta_2} = \frac{(0.6857)(0.0206)}{(1.9786)} = 0.0071$$

NOTE: $\Delta\alpha$ IS MEASURED FROM BISECTOR OF 2α

$\Delta\alpha = 0.41$ degrees toward LASALLE

$\Delta\alpha \approx 0°25'$

$\cos\Delta\alpha = 1.0000$

$$\tan\Theta_3 = \frac{\cos\Delta\alpha}{\cos\alpha}\;\frac{\sin\Theta_1 + \sin\Theta_2}{\cos\Theta_1 + \cos\Theta_2} = \frac{(1.0000)(+0.2314)}{(0.8247)(1.9786)} = 0.1418$$

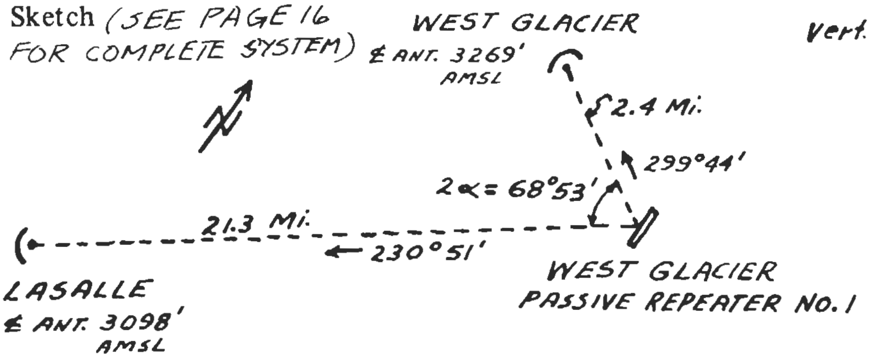
$\Theta_3 = 8.07$ degrees (8° 04')

(when $\tan\Theta_3$ is negative) → ☐ Up

(when $\tan\Theta_3$ is positive) → ☒ Down

Sign Convention: Cosines and tangents are positive. Sines are positive when the angle slopes downward from the passive repeater, and negative when the angle slopes upward from the passive repeater. Note that $\Delta\alpha$ always rotates the passive bearing towards the path with the least vertical angle, Θ_1.

Sketch (SEE PAGE 16 FOR COMPLETE SYSTEM)



$$\text{Vert. } \angle,\ \theta_1 = \tan^{-1}\frac{(5907-3098)+303}{(21.3)(5{,}280)}$$

$\theta_1 = 1.58°$ down from passive

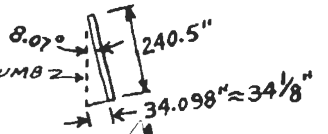
$$\text{Vert. } \angle,\ \theta_2 = \tan^{-1}\frac{(5907-3269)}{(2.4)(5{,}280)}$$

$\theta_2 = 11.76°$ down

$$\text{Earth's Curvature Correction} \approx \frac{(\text{Miles})^2}{1.5}\ \text{Feet}$$

$$\text{For 21.3 Mile path} = \frac{(21.3)^2}{1.5} = 303\ \text{Ft.}$$

REFERENCE FOR SETTING FACE ANGLE →



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PASSIVE REPEATER BEARING CALCULATION SHEET FOR Θ_3 AND $\Delta\alpha$

Passive Size	Site	Location

Horizontal included angle between paths: $2\alpha =$ degrees

One-half the horizontal included angle $\alpha =$ degrees

Smaller vertical path angle from horizontal: $\Theta_1 =$ degrees ☐ Up ☐ Down

Larger vertical path angle from horizontal: $\Theta_2 =$ degrees ☐ Up ☐ Down

$\cos\Theta_1 =$	$\cos\Theta_1 =$
$\cos\Theta_2 =$	$\cos\Theta_2 =$
$\cos\Theta_1 + \cos\Theta_2 =$	$\cos\Theta_1 - \cos\Theta_2 =$
$\sin\Theta_1 =$	$\tan\alpha =$
$\sin\Theta_2 =$	$\cos\alpha =$
$\sin\Theta_1 + \sin\Theta_2 =$	

$$\tan\Delta\alpha = \tan\alpha \; \frac{\cos\Theta_1 - \cos\Theta_2}{\cos\Theta_1 + \cos\Theta_2} = \frac{(\qquad)(\qquad)}{(\qquad)} =$$

$\Delta\alpha =$ degrees toward

$\cos\Delta\alpha =$

$$\tan\Theta_3 = \frac{\cos\Delta\alpha}{\cos\alpha} \; \frac{\sin\Theta_1 + \sin\Theta_2}{\cos\Theta_1 + \cos\Theta_2} = \frac{(\qquad)(\qquad)}{(\qquad)(\qquad)} =$$

$\Theta_3 =$ degrees (when $\tan\Theta_3$ is negative) → ☐ Up (when $\tan\Theta_3$ is positive) → ☐ Down

Sign Convention: Cosines and tangents are positive. Sines are positive when the angle slopes downward from the passive repeater, and negative when the angle slopes upward from the passive repeater. Note that $\Delta\alpha$ always rotates the passive bearing towards the path with the least vertical angle, Θ_1.

Sketch

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EFFECTIVE AREA AND POLARIZATION ROTATION

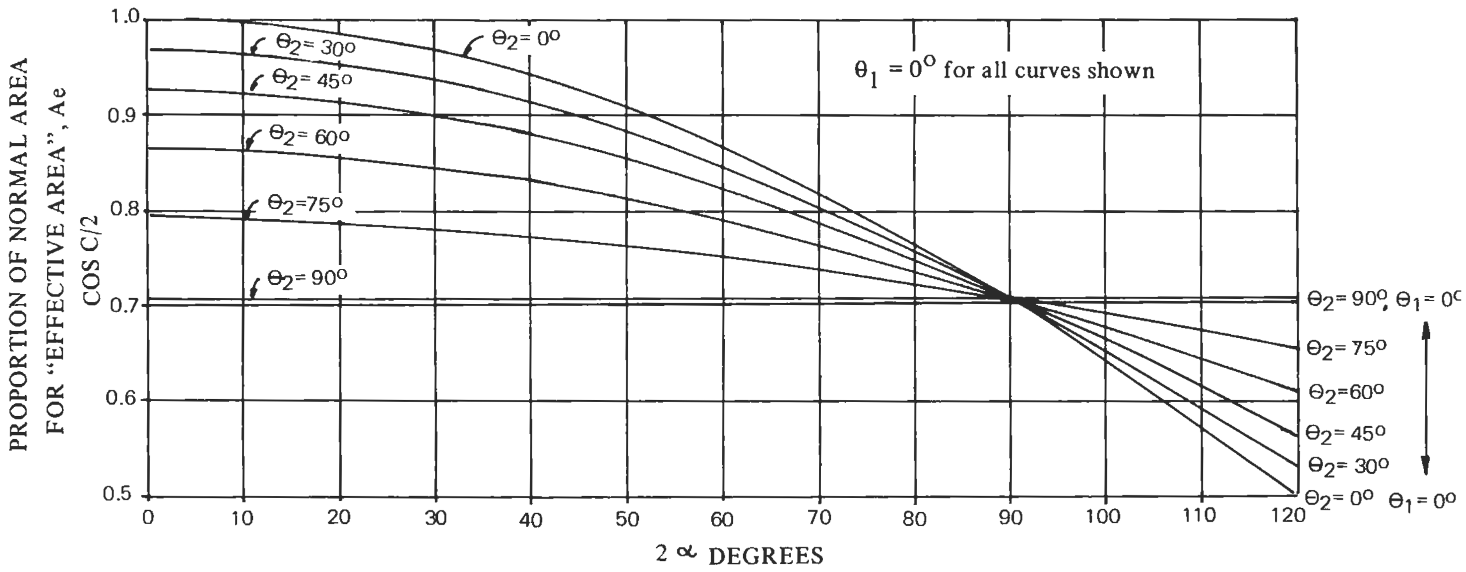
When the vertical angles, θ_1 and θ_2, are large (perhaps 20 degrees or more), it may be important to determine the effective area more exactly than that approximated from the horizontal angle, 2α . This effective area should be used for the gain calculations.

FIG. 7–2 illustrates the change in the effective area with one vertical angle held constant at 0° and the other vertical angle varying from 0° to 90° along with a range of 2α variation from 0° to 120°. The cos C/2 relates the effective area and normal area for all shapes and sizes of reflectors. Note that the effective area increases for increasing 2α beyond 90° and increases in θ_2.

Polarization rotation is the change in polarization angle caused by reflecting a linear-polarized radio beam with a flat surface reflector. This rotation or skewing may be significant where θ_1 and θ_2 are large.

An example calculation for effective area and polarization rotation is on page 69. The blank form on page 70 is intended to be used for calculations, where the page is copied with an office copier.

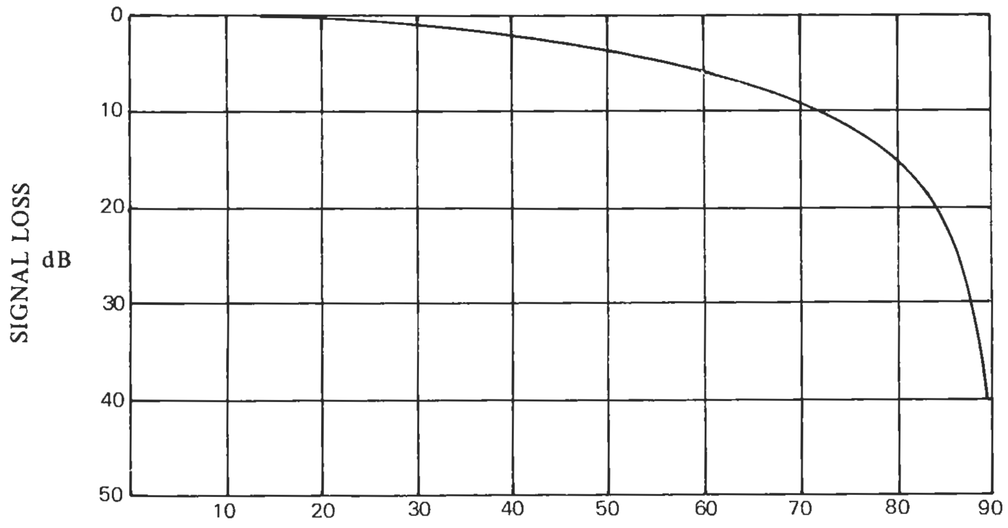
FIG. 7--3 illustrates the loss in signal level to expect for various polarization mismatches. For most passive repeater applications, these losses are very small, but for some transmission considerations the loss in cross--polarization isolation may be significant. The antenna feed(s) is sometimes rotated to compensate for the loss in cross polarization isolation. (orthogonal polarizations remain orthogonal).



HORIZONTAL INCLUDED ANGLE, 2α VS. EFFECTIVE AREA COEFFICIENT, COS C/2

(EFFECTIVE AREA, A_e = NORMAL AREA X COS C/2)

FIGURE 7 - 2



$\Delta\phi$ DEGREES	$10 \log \frac{1}{(\cos\Delta\phi)^2}$ dB
10	0.13
20	0.54
45	3.01
60	6.02
75	11.7

POLARIZATION SHIFT $\Delta\phi$ DEGREES
POLARIZATION SHIFT VS. THEORETICAL SIGNAL LOSS
FIGURE 7- 3

EXAMPLE COMPUTATIONS WEST GLACIER #2A 1624-8

FROM COMPUTATION SHEET FOR θ_3 & $\Delta\alpha$ $\theta_1 = 12.5°$ $\theta_2 = 16.33°$ $2\alpha = 68.5°$ $\Delta\alpha = 0.33°$ $\theta_3 = 17.28°$ down

Passive Repeater Effective Area, Ae, and Polarization Rotation, $\Delta\phi$, Calculation Sheet

NOTE

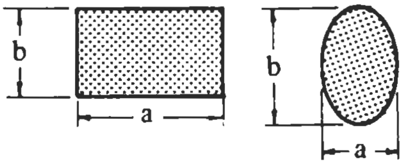
Work these calculations in conjunction with the face angle, θ_3, and horizontal correction angle, $\Delta\alpha$, calculations.

Effective Area, Ae = (Normal Area)(cos $C/2$)

Where: C is the true angle between incident & reflected beams.

Normal Area = (a x b) for rectangular passives

Normal Area = (a x b) $\frac{\pi}{4}$ for elliptical reflectors



$$\cos \frac{C}{2} = \frac{\sin\theta_1 + \sin\theta_2}{2\sin\theta_3} = \frac{(0.4976)}{2(0.2970)} = +0.8377$$

Ae = (16)(24)(0.8377) = 321 SQ. FT.

$C/2$ = 33.10 degrees, sin $C/2$ = +0.5461

C = 66.20 degrees, sin C = +0.9150 cos C = $\oplus$ 0.4035

Polarization rotation $\Delta\phi = \phi_1 + \phi_2 - 180°$, where:

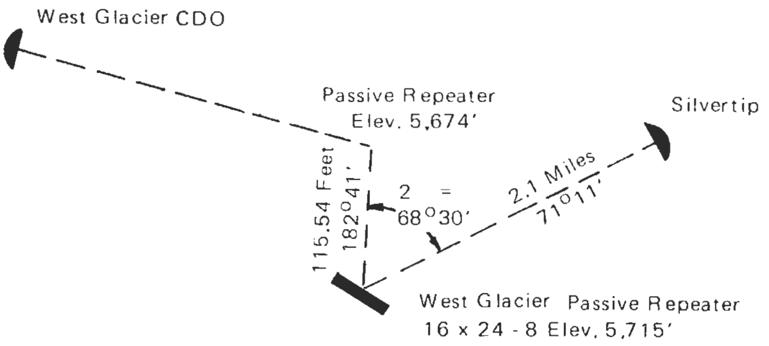
$$\cos\phi_1 = \left[\frac{\sin\theta_1 - \sin\theta_2 \cos C}{\cos\theta_2 \sin C}\right] = \left[\frac{(\oplus 0.2164) - (\oplus 0.2812)(\oplus 0.4035)}{(+0.9596)(+0.9150)}\right] = \oplus 0.1172$$

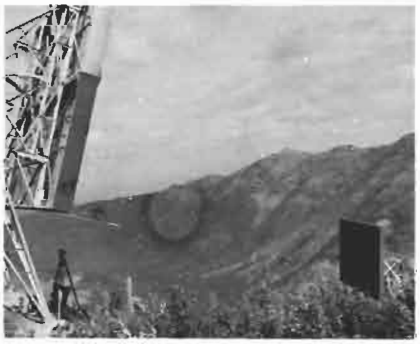
ϕ_1 = 83.3 degrees

$$\cos\phi_2 = \left[\frac{\sin\theta_3 - \cos\frac{C}{2}\sin\theta_1}{\sin\frac{C}{2}\cos\theta_1}\right] = \left[\frac{(\oplus 0.2970) - (+0.8377)(\oplus 0.2164)}{(+0.5461)(+0.9763)}\right] = \oplus 0.2170$$

ϕ_2 = 77.5 degrees

$$\Delta\phi = \phi_1 + \phi_2 - 180° = 83.3 + 77.5 - 180° = \overset{+}{\ominus}\ 19.2°$$





SEE PAGE 16 FOR COMPLETE SYSTEM

Passive Repeater Effective Area, Ae, and Polarization Rotation, $\Delta\phi$, Calculation Sheet

NOTE

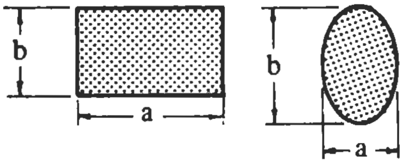
Work these calculations in conjunction with the face angle, θ_3, and horizontal correction angle, $\Delta\alpha$, calculations.

Effective Area, Ae = (Normal Area)(cos $C/2$)

Where: C is the true angle between incident & reflected beams.

Normal Area = (a x b) for rectangular passives

Normal Area = (a x b) $\frac{\pi}{4}$ for elliptical reflectors



$$\cos\frac{C}{2} = \frac{\sin\theta_1 + \sin\theta_2}{2\sin\theta_3} = \frac{(\qquad\qquad)}{2(\qquad\qquad)} = +\underline{\qquad\qquad}$$

Ae = (   )(   ) = ________________

$C/2$ = ____________ degrees, $\sin C/2$ = + ____________

C = ____________ degrees, sin C = + ____________ cos C = ± ____________

Polarization rotation $\Delta\phi = \phi_1 + \phi_2 - 180^\circ$, where:

$$\cos\phi_1 = \left[\frac{\sin\theta_1 - \sin\theta_2\cos C}{\cos\theta_2\sin C}\right] = \left[\frac{(\pm\qquad)-(\pm\qquad)(\pm\qquad)}{(+\qquad)(+\qquad)}\right] = \pm\underline{\qquad\qquad}$$

ϕ_1 = ____________ degrees

$$\cos\phi_2 = \left[\frac{\sin\theta_3 - \cos\frac{C}{2}\sin\theta_1}{\sin\frac{C}{2}\cos\theta_1}\right] = \left[\frac{(\pm\qquad)-(+\qquad)(\pm\qquad)}{(+\qquad)(+\qquad)}\right] = \pm\underline{\qquad\qquad}$$

ϕ_2 = ____________ degrees

$$\Delta\phi = \phi_1 + \phi_2 - 180^\circ = \underline{\qquad\qquad} + \underline{\qquad\qquad} - 180^\circ = \pm\underline{\qquad\qquad}$$

NOTE $\Delta\phi$ is negative when counterclockwise as viewed from the right hand path when facing the reflector.
$\Delta\phi$ is negative when clockwise as viewed from the left hand path when facing the reflector.
(regardless of which paths are assigned θ_1 & θ_2 in the equations)

Sign Convention: $\sin\theta_3$ is positive when face angle is down, negative when up.

cos C, cos ϕ_1, cos ϕ_2 { positive between 0°-90°
negative between 90°-180°

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Customer	Computations by:	Date

CHAPTER VIII

PLANNING PASSIVE REPEATER INSTALLATIONS

PERMITS

Before construction begins it is required that a permit from the FCC is acquired by the customer. Application information for the permit is similar to that required for an active station and antenna. Geographic location, frequency, passive size, and elevation need to be stated in the application. Other local, state or forest service permits should also be acquired by the customer prior to construction.

SITE ACCESS AND WEATHER

The various ways to gain access to the site should be investigated. The access should allow for safe and practical methods of transporting men and material. Access by helicopter is often practical. A permanent access road is not required as only a few inspection trips to the site may be needed after initial installation of the unit. Portable power plants are convenient during construction but are not a necessity. Construction can be accomplished in two phases. One phase is placement of footings and anchor bolts and another is erection of the structure. It is sometimes more economical if design and installation of the footings is accomplished by people in the local area. Sometimes the season of the year will dictate construction schedules. Rain, snow, mud, ice, and high velocity winds will add to construction costs.

SITE TOPOGRAPHY

Large rocks and trees can cause construction problems and obstruct microwave paths. Path clearances for a passive repeater should be considered as being the same as those required for an active repeater station. Rock out-croppings make footing excavations difficult to accomplish. Sometimes passives with 15 foot ground clearance can overcome site obstructions too high for passives with 8 foot ground clearance. Passives with special interfaces or tower mounted passives may be employed where tree and rock removal is not desirable or more expensive than the increased structure costs.

For standard ground mounted passive repeaters, the tops of footings must be level with each other. On some sloping sites or rough terrain a concrete pier could project several feet above the ground. For this situation one of the following alternatives may be available to keep the total concrete quantities at a minimum: (1) The site might be leveled; (2) The tops of footings may be sloped on sites where the slope is uniform in the general direction of the passive bearing; (3) The standard supporting structure may be modified for placement on stepped footings; (4) Special steel interfaces may be designed to support the standard supporting structure. In general, interface steel is more economical than concrete piers when access to the site must be accomplished with helicopters or four-wheel drive vehicles over extremely rough terrain.

For the alternatives of site development or passive modification, the costs of site development must be compared with the increase in costs for the modified passive along with a comparison of the final over-all appearances of site and structure.

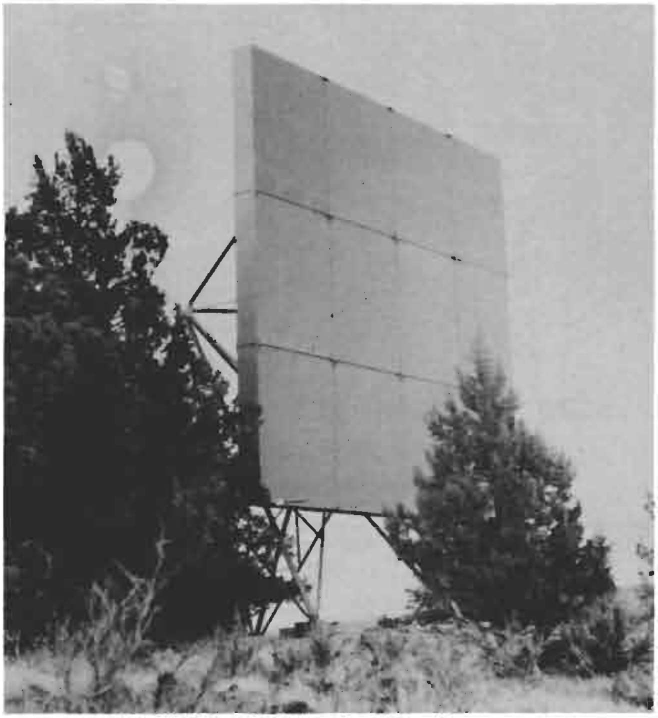
AVAILABILITY OF FOUNDATION MATERIAL AND VEHICLES FOR TRANSPORTATION

Some sites may be reached with a concrete truck, which hauls the concrete a short distance from a permanent batching plant. Other sites may be reached only by special four-wheel drive or track driven vehicles with limited hauling capacity. For many sites the preferred method of conveying men and material to the site employs the use of a helicopter.

SURVEYING

The details required for surveying depend upon the stage of the system planning. Information from topographical maps can suffice for very preliminary plans. As the planning progresses, visits to the sites are necessary. A map study and site visit usually will provide enough information for cost estimating or budgetary planning. Final construction planning and engineering often require more detail. A survey may be required for property acquisition. The vertical angles to the other sites along with the angle included between the path azimuths determine the exact size of a few members that vary in length for the particular vertical face angle. It is adviseable to stake the exact position of the footings. The footings should be placed such that the reflector face does not vary after erection is completed more than $1/3^{\circ}$ from the optimum position.

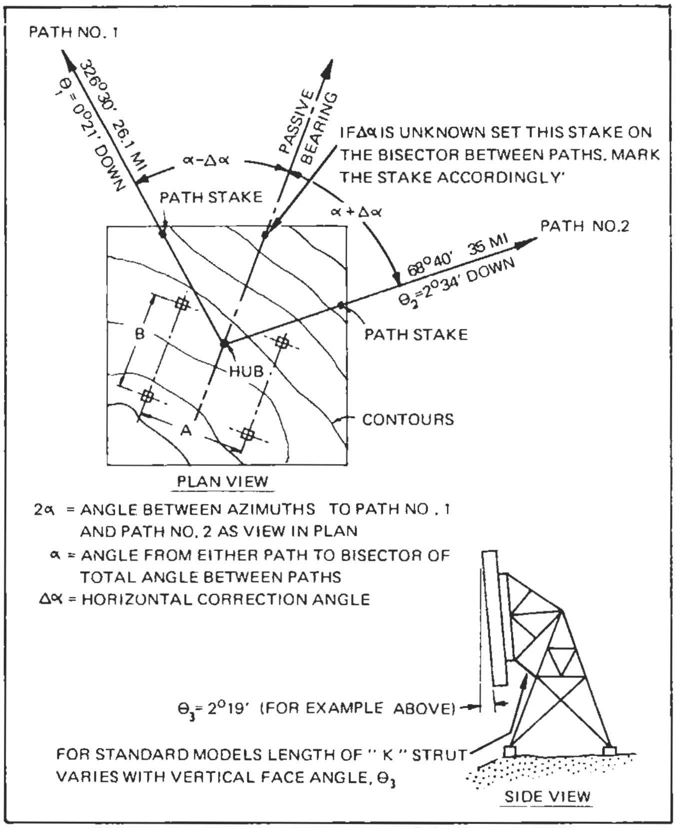
A visit to the site will reveal whether a detailed survey is required with respect to the surface topography. A site that does not vary in elevation more than a few feet does not require contours of one foot intervals. However, a steep sloping site, usually in excess of 10° slope, should be surveyed for plotting contour intervals of 1 foot or ½ meter.



A MICROFLECT 30'× 32' GROUND MOUNTED PASSIVE REPEATER

Azimuths and vertical angles of the paths to the other sites should be determined within a few minutes of arc.

Particular attention should be given to detail when surveying the site for a double passive repeater installation. The close proximity of the reflectors can make seemingly insignificant elevation and angular deviations very important. Refer to Appendix.



EXAMPLE PLAN OF FOOTING PLACEMENT

EXAMPLE OF "Δα" AND " Θ3 " DETERMINATION

Refer to the "Example Plan of Footing Placement".

$$\tan \Delta\alpha = \tan \alpha \left(\frac{\cos \Theta_1 - \cos \Theta_2}{\cos \Theta_1 + \cos \Theta_2} \right) =$$

$$\tan \Delta\alpha = \left[\tan\left(\frac{102^\circ\ 10'}{2} \right) \right] \left[\frac{(\cos 0^\circ\ 21' - \cos 2^\circ\ 34')}{(\cos 0^\circ\ 21' + \cos 2^\circ\ 34')} \right]$$

$$\tan \Delta\alpha = 0.0060$$

$$* \Delta\alpha = 0^\circ\ 02'$$

This magnitude is insignificant*** for setting the bearing stake; the passive bearing stake may be set on bisector of the 2 α angle. This may be done for Δα angles of approximately 0° 10' or less.

$$\tan \Theta_3 = \left(\frac{\cos \Delta\alpha}{\cos \alpha} \right) \left(\frac{\sin \Theta_1 + \sin \Theta_2}{\cos \Theta_1 + \cos \Theta_2} \right)$$

$$\tan \Theta_3 = \frac{(\cos 0^\circ\ 02')\ (\sin 0^\circ 21' + \sin 2^\circ\ 34')^{**}}{(\cos 51^\circ\ 05')\ (\cos 0^\circ\ 21' + \cos 2^\circ\ 34')}$$

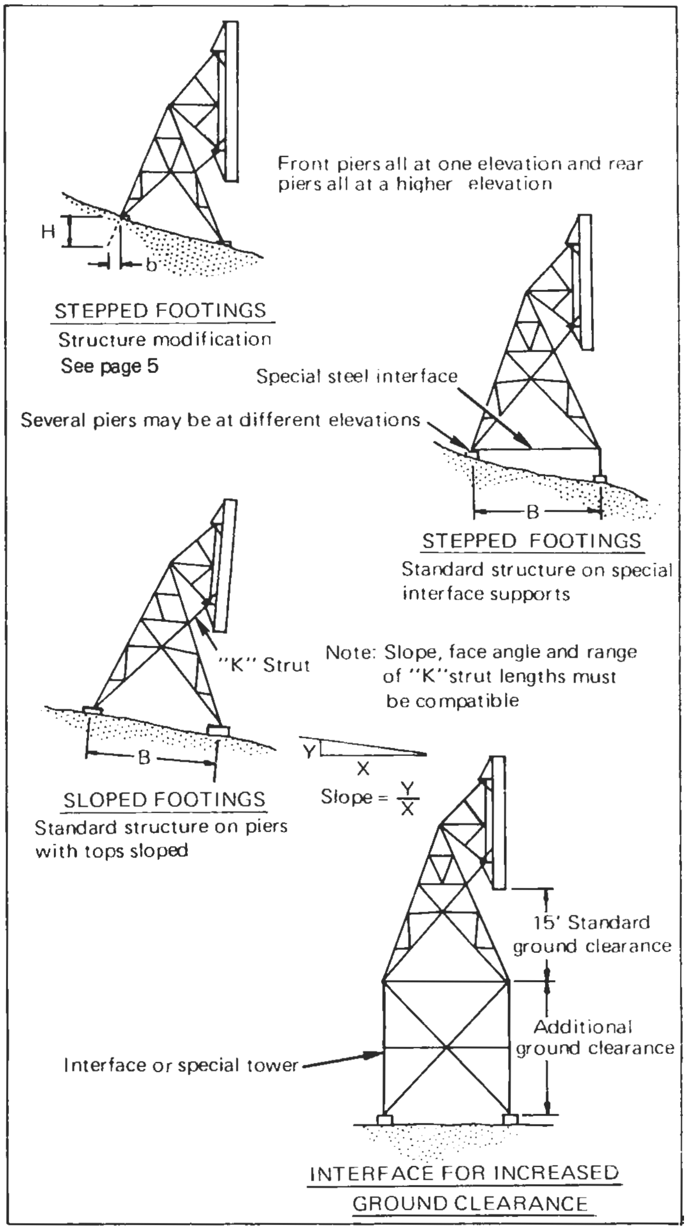
$$\tan \Theta = 0.04052$$

$$\Theta_3 = 2^\circ\ 19' \text{ down}$$

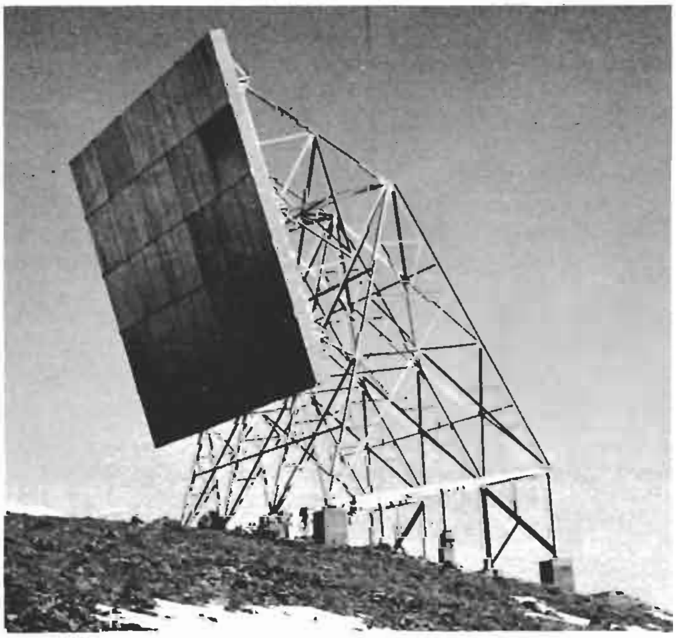
* Δα correction must be made in correct direction: toward path with least vertical angle.

** caution must be made that algebraic signs (+ or –) are correct.

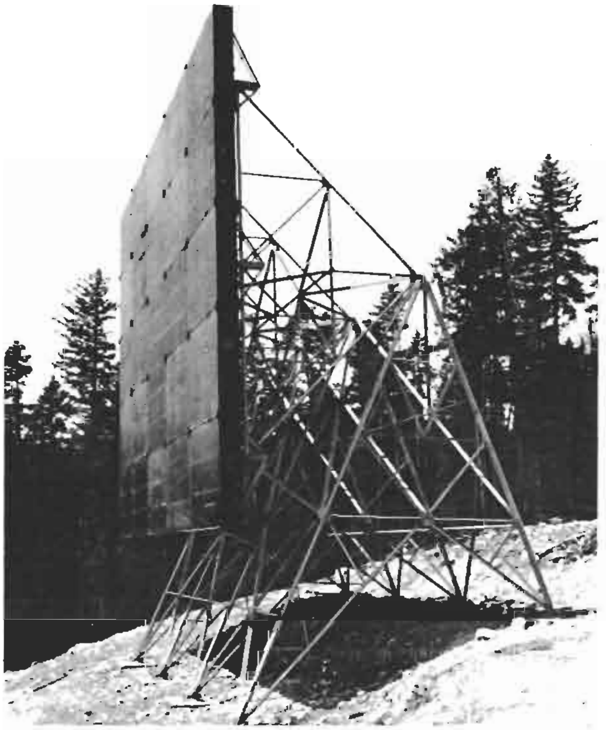
*** Some optical settings are final and should be within one minute of arc (0.02°)



EXAMPLES OF SPECIAL FOOTING ARRANGEMENTS AND INTERFACES



MICROFLECT 40'x50' PASSIVE REPEATER WITH INTERFACE STRUCTURE



40'x50' PASSIVE REPEATER WITH STEPPED FOOTINGS

ERECTION

The erection methods used for the smaller ground-mounted passive repeaters (8’ x 10’ thru 14’ x 16’) are those typically used for small steel structures of about 30 ft. in height. Conventional hand tools with light simple rigging for lifting the panels in place are all that are needed.

The larger ground mounted passives (16’ x 20’ to 40’ x 60’ with 8’ and 15’ ground clearance) have been designed so that the erection procedures and equipment are not elaborate. The erection equipment used will usually depend upon the site access and it follows that the more help from power equipment and booms, the faster the erection can be completed. All standard units can be erected with hand tools, hand winches and light rigging for lifting and holding the panels in place.

After the foundations and anchor bolts are in place the procedure will generally be the following:

(1) Check the anchor bolt spacing and orientation.
(2) Study the erection drawings and notes thereon very carefully.
(3) Place the shoe plates on the anchor bolts, installing only the outside bolts of the horizontally positioned bolts, so they may act as a hinge.
(4) Assemble a side elevation or bent (or part of one, depending upon the lifting aids available) and then raise the assembled steel to a vertical position using the shoe plate as a hinge.
(5) Complete the side elevation if necessary and install all of the shoe plate bolts.
(6) Complete the bracing between bents
(7) Install the brackets and adjusting mechanism.
(8) After steel assembly is complete, lift the panels in place a row at a time (the bottom row installed first).

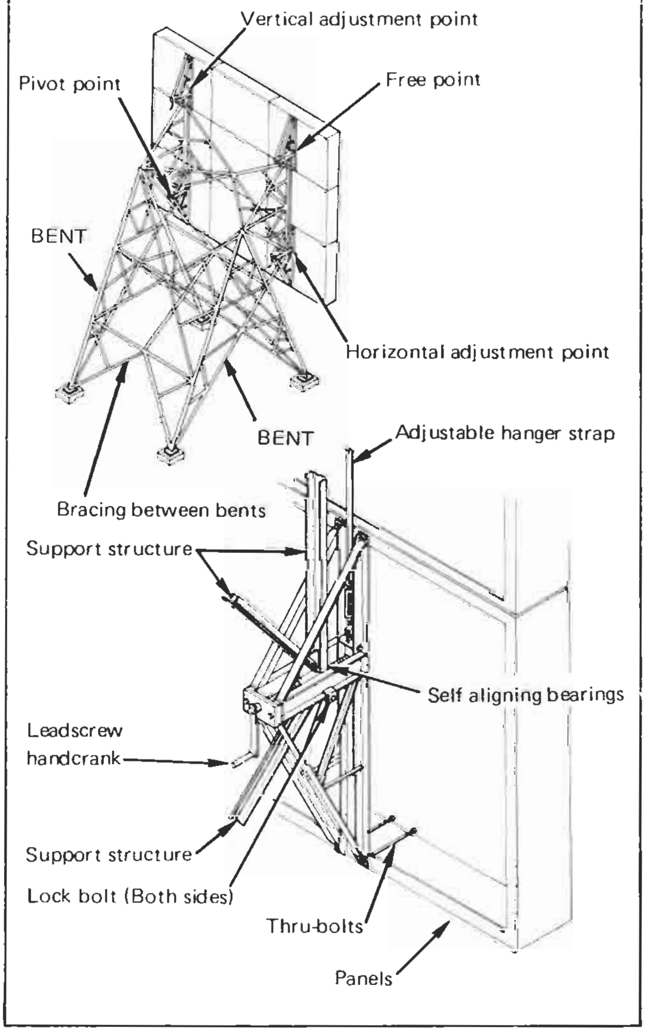
ADJUSTMENTS

Typically, adjusting ranges for units allow for one to two degrees rotation from a neutral position in a horizontal or vertical plane.

Adjusting mechanisms for the larger passives (16’ x 20’ thru 40’ x 60’) consist of adjustable hanger straps, self-aligning bearing nuts, lead screw with attached hand crank and locking bolts.

The adjusting mechanisms may be available at four or more points. The adjustment is based on three of the points determining a plane parallel to the face of the panels. The fourth point is a free point.

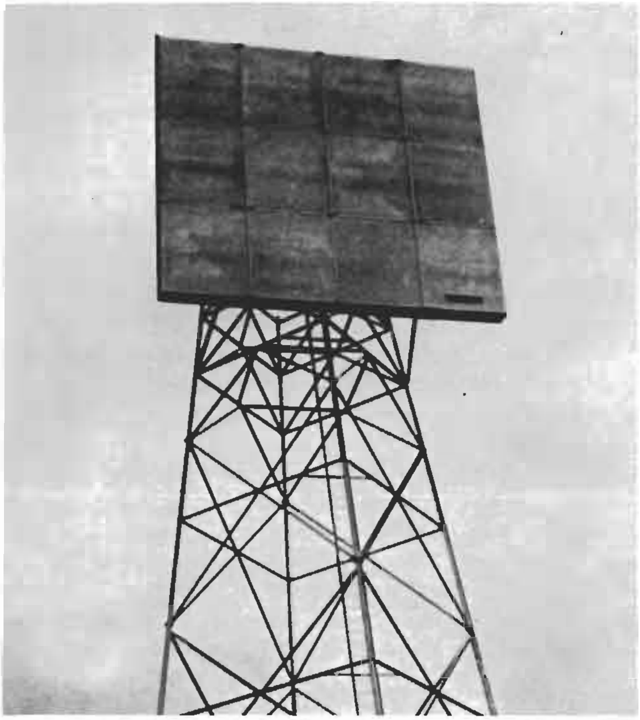
For the very large passives, such as 40’ x 50’ & 40’x 60’ more than four points of adjustment are available and care must be taken to maintain the face flatness requirements. Refer to appendix.



DETAILS OF TYPICAL ADJUSTING MECHANISM

ALIGNMENT

It is recommended that an optical alignment of the passive using surveyor’s instruments be made immediately after erection is complete. If the optical alignment is done very carefully, a signal well above noise will be available through the passive and only slight adjustments requiring minimum time will put the passive face in the optimum position. Sometimes a very careful optical alignment will be all that is needed. See appendices for some alignment procedures.



A MICROFLECT 30x32 TOWER MOUNTED PASSIVE REPEATER. IT IS 67 FEET FROM THE LOWER EDGE OF THE PASSIVE TO THE GROUND.

TOWER-MOUNTED PASSIVE REPEATERS

The following alternatives may be available when a tower-mounted passive repeater installation is planned:

(1) For passive sizes 8' x 10' thru 16' x 20' standard passives and towers are available from Microflect Co. with the passives adaptable to mounting on 4½" O.D. pipes.

(2) Modified versions of standard passives and towers may be obtained from Microflect Co. The modifications may be the results of a specified increase in the design wind loading and/or a required change in geometry from the standard configuration.

(3) A standard passive repeater may be obtained from Microflect Co. (or part of a standard model) to be mounted on a tower fabricated by others, perhaps an existing tower (or chimney).

SITE PLANNING

The site access and topography must be evaluated in the same manner as ground mounted passive and microwave tower installations.

The relative orientation of the tower and the passive along with the position of the tower on the site is a very important part of the plans. The larger sizes should be planned with the same considerations used for ground-mounted passives (8' & 15' ground clearance). Some smaller sizes have more versatile mounting arrangements and a greater adjusting range than the largest models.

TOWER ATTACHMENT

The larger size passives (30' x 32' to 40' x 60') require specific, rigid attaching points be incorporated in the tower geometry.

Intermediate size passives (16' x 20' to 24' x 30') require complete coordination with the tower designer for modification of standard tower designs or design of special adaptive fittings and support members.

Smaller size passives (8' x 10' to 14' x 16') are more versatile with respect to possible mounting positions and adaptibility to existing tower designs, but attaching devices must be designed for exact fitting or specified from standard or universal type clamps and pipe mount supporting schemes.

ERECTION

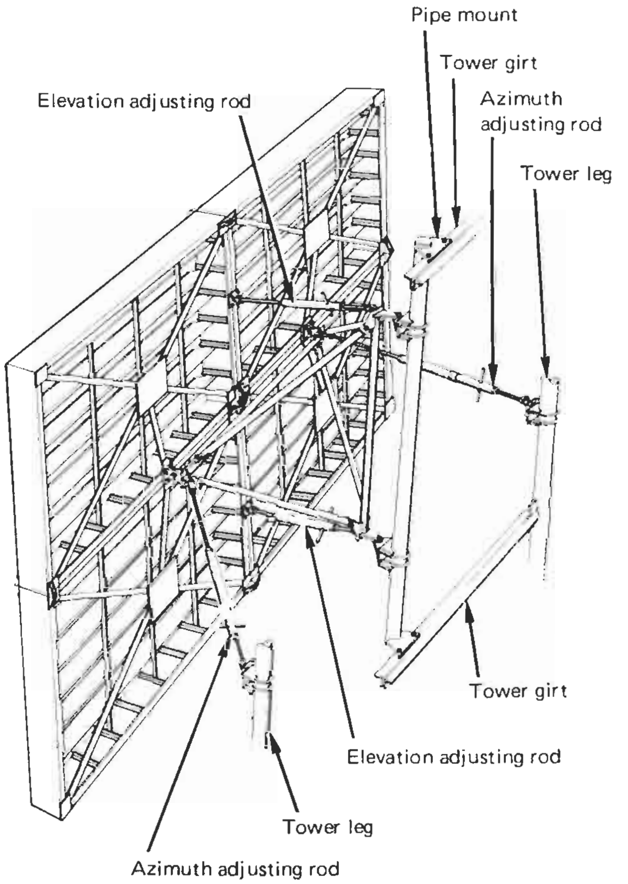
The erection procedures vary with the size of passive and height of tower required. Often the structure can be completed with tools and winches and other light rigging typically used for erection of self-supported microwave towers.

For the smaller passives the assembly of the complete unit may be accomplished on the ground with hand tools and then the unit is lifted in position on the completed tower and passive attaching points.

For the larger units the passive support steel is assembled as a part of the tower and then the aluminum panels are lifted in place a row at a time.

ADJUSTING DEVICES

The smaller tower-mounted passives and standard wall-mounted passives have pipe-type azimuth and elevation adjusting rods as shown in the figure below.

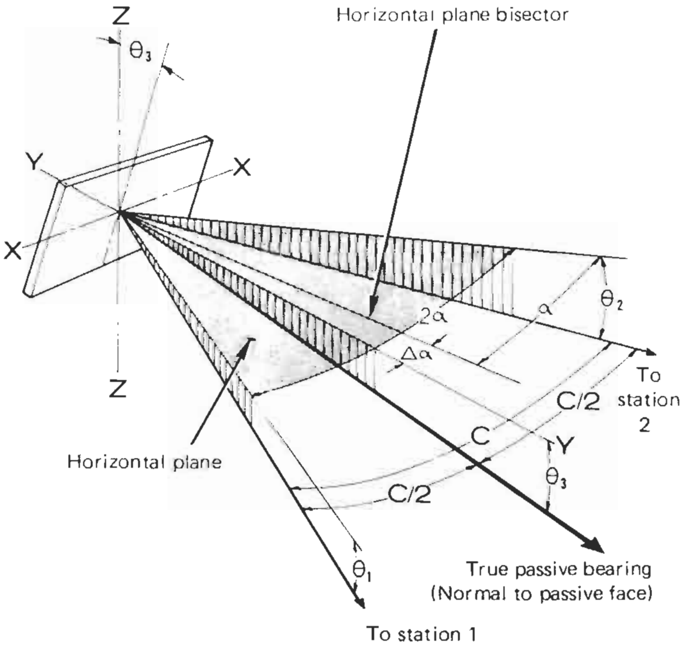


TYPICAL MOUNTING ARRANGEMENT FOR A 16x20 TOWER MOUNTED PASSIVE REPEATER

The adjustment is accomplished by backing off the lock nuts and rotating the handle. When the optimum position is reached, the locknuts are tightened to prevent movement of the handle. Azimuth and elevation adjusting limits may be at least ± 5° about the calculated normal position for the pipe-type adjusting device.
The larger tower mounted passives will usually have adjusting mechanisms similar to the large ground mounted passives.

ALIGNMENT

Optical alignment procedures similar to those employed for the large ground mounted passives are recommended. However, special attention may be required for the horizontal correction angle, $\Delta\alpha$, where large vertical angles on one path are a part of the system geometry.



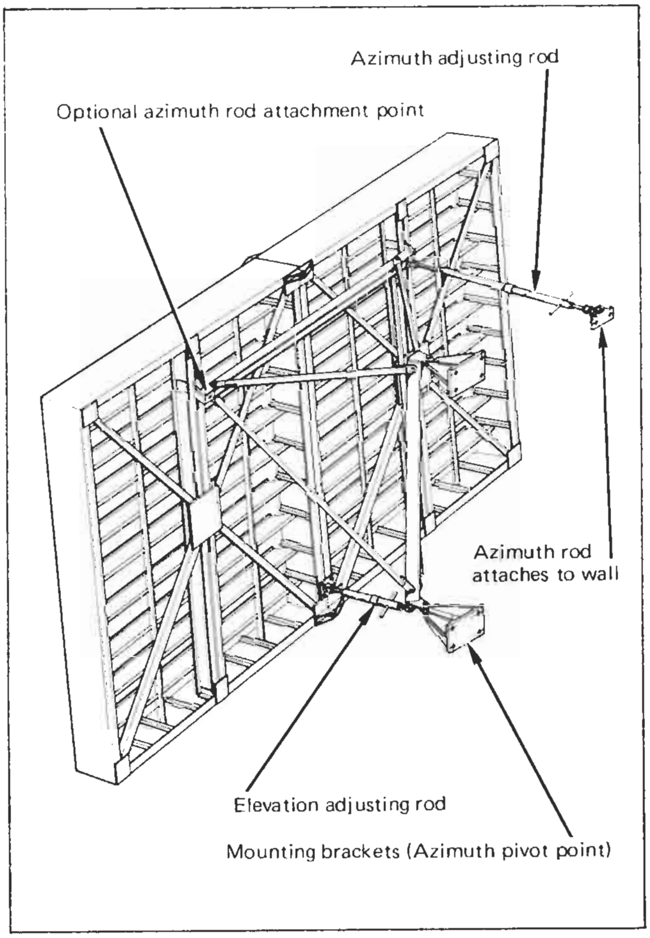
PATH GEOMETERY

WALL MOUNTED PASSIVE REPEATERS

Standard wall mounted passive repeaters are available in sizes from 6' x 8' to 16' x 20' with some standard devices for attaching to building surfaces. The construction of these passives are identical or very similar to the smaller tower-mounted passives.

The following items require investigating for mounting passive repeaters on building walls:

(1) Wall construction–material, thickness, supports inside and outside surface.
(2) Fastening devices (methods to be compatible with wall construction)–thru bolts, concrete anchors, additional steel interface.
(3) Load allowed on building wall at fastening points.
(4) Angle passive makes with surface of wall in plan–
    (a) A point of attachment for the azimuth adjusting and stabilizing struts must be determined along with the required length of these struts.
    (b) If the standard unit will not accommodate the angle the passive face makes with the wall a special steel mount or interface may be required.
(5) Face angle of passive (determines median length of elevation adjusting rod).
(6) Place of assembly and method of lifting in place–
    (a) The passive may be assembled at the ground level and hoisted in place on the installed wall attachments.
    (b) The passive may be assembled on a roof and lifted in place on a penthouse wall, elevator shaft, or some higher wall surface on the building.



DETAILS OF STANDARD MICROFLECT WALL MOUNTED PASSIVE REPEATER

PASSIVE REPEATER GROUNDING CONSIDERATIONS

The primary purpose of grounding a microwave structure is to protect equipment from damage caused by lightning. As passive repeaters usually stand alone on mountains and remote hill tops without electronic equipment or power sources, it is likely no special lightning protection is required. The passive repeater is a self protected device if the lightning's energy can be dissipated through the earth without damage to the piers. (Some recent information has shown that concrete encased grounding electrodes can be effective and steel-reinforced concrete tower footings and guy anchors can be immune to lightning damage with the proper placement of steel reinforcing and anchors to insure good electrical continuity.) However, there is no guarantee that steel-reinforced concrete footings can dissipate the energy from lightning strokes for all installations. Therefore, conservative approaches to a few passive installations have been to ground them to be safe and sure. Economically this approach may prove to be very expensive insurance for the small probability of damage from lightning when the usual site conditions for ground-mounted passives are considered. Broken rock and solid rock are often encountered. Sometines reinforcing has to be grouted into the solid rock to obtain resistance to the uplifting forces at the piers. Driving ground rods is often impossible. Placing ground rods in drilled holes or rocky trenches has dubious value over the probable effectiveness of the piers. More elaborate grounding systems in rocky outcroppings require maintenance. Much time, material and expense can be accrued with practically no value obtained.

Grounds are also installed for personnel safety and carrying line-to-ground fault currents where structures are near power lines. Consideration should be given to the wire size that can carry the maximum line-to-ground fault current during the time it takes for breakers or fuses to clear the fault.

It can be concluded that grounding of passive repeaters requires special attention for some installations but grounding should not be a general requirement for passive repeaters.

ARCTIC DESIGN

The more severe the weather conditions, the more useful is the application of passive repeaters. It is perfectly logical to locate a passive repeater on the top of a mountain range that is completely inaccessible during the winter, but it is usually impractical to place an active relay station on the same site where the equipment would be ignored for long periods of time and the power line subject to repeated failures. The key to the problem is to make certain that the passive repeater is properly designed for the duty it is expected to perform. To meet the need for a heavy duty passive, Microflect Company has developed "Arctic" models designed for the conditions outlined in the Appendix.

To support the tons of additional loading called for in the above specification the design incorporates "snow load" structural members and given additional bracing to withstand the combination ice and wind loading. Several standard sizes are available in the arctic design. In addition, Microflect Company is ready to custom design passive repeaters to meet any unusual requirements.

Effects of severe icing conditions on the reflecting efficiency of a passive can be reduced by painting the reflecting surfaces, front and back, with a flat black enamel paint. The black paint absorbs heat from the sun and significantly reduces the thickness and duration of an ice load. We supply panels, shop painted, any color for a nominal additional cost.

Deicing kits, which are also described in detail in the Appendix have also proven to be practical to promote the shedding of ice after some has accumulated. The deicing kits consist of covers which are made of a plastic coated nylon fabric. The covers are fitted to the aluminum panels with PVC pipe frames. Black covers are supplied unless green is specified.

SUMMARY

PLANS AND COST ESTIMATES FOR PASSIVE REPEATER INSTALLATIONS

Site ______________________________

Location ______________ Size of passive ______________

☐ Ground mounted
☐ Tower mounted
☐ Wall mounted

Special features (Interfaces, ground clearances, face angles, materials, back covering, etc.) ______________

____

____

____

Site conditions (Remarks on location, weather, access, concrete availability, tower for tower mount, building for building mount, etc.)

____

____

____

____

____

____

COST ESTIMATES

ENGINEERING (Includes site visits) ______________ $ ______

SURVEYING ______________ ______

SITE PREPARATION ______________ ______

MATERIAL (F.O.B. Salem, Oregon)

- PASSIVE REPEATER ______________ ______
- INTERFACE ______________ ______
- TOWER ______________ ______
- BUILDING SUPPORTS ______________ ______

FREIGHT ______________ ______

FOUNDATIONS ______________ ______

GROUNDING ______________ ______

BUILDING OR EXISTING TOWER MODIFICATIONS AND ADDITIONS ______________ ______

ERECTION ______________ ______

FINAL OPTIMIZING (Include travel costs) ______________ ______

TOTAL COST $ ______

TIME SCHEDULE FROM TIME OF PLACING ORDER

SHIP MATERIAL ______________ ______ WEEKS

INSTALL FOUNDATIONS AND GROUNDING ______________ ______ WEEKS

ERECTION ______________ ______ WEEKS

OPTIMIZE (Job finished) ______________ ______ WEEKS

CHAPTER IX

PAINTING, COVERING, and CAMOUFLAGING PASSIVE REPEATERS

Hundreds of Microflect passive repeaters exist on microwave communications systems in various countries throughout the world and particularly across the width and breadth of the North American Continent. Most of these passive repeaters are Microflect standard models consisting of galvanized steel for the basic support structure and aluminum-alloy panels for the reflecting surface. Problems occur only with a very small percentage of passive repeater applications due to the particular environment of the installation. Some cold-weather environments cause ice accumulation on the reflecting face with a resulting signal degradation not accounted for by system design. Also some orientations of large passive repeaters used at the higher microwave frequencies cause problems by absorption of the sun's radiation. Occasionally there are concerns about the impact of a passive repeater on the environment. Anxiety about appearances can occur. The effects of their appearances on the environment usually are greatly exaggerated, and the proposed environmental problems seldom are weighed properly with total environmental effects, benefits, alternatives, and costs.

REASONS FOR PAINTING OR COVERING PASSIVE REPEATERS

One or more of the following questions are involved in proposed plans to paint and/or cover a passive repeater.

a. Will the passive repeater appearances be acceptable in the planned location?
b. Can light reflections from the aluminum surfaces cause undue attention to the passive repeater?
c. Will the orientation of the passive likely allow absorption of the sun's radiation, in combination with resulting temperature differentials on the panels, to cause face distortion beyond accepted tolerances?
d. Will large accumulations of ice likely occur repeatedly on the reflecting face of the passive repeater?

PAINTING AND/OR COVERING TO IMPROVE APPEARANCES AND REDUCE LIGHT REFLECTIONS

A flat-finish painted surface can be used to produce uniformity of coloring* and to avoid light reflections. For appearances, it may be desireable to paint the entire unit a green or tan color to match trees, grass, or the general terrain.

However, painting can cause problems by increasing the amount of the sun's radiation absorbed over that amount absorbed by the natural surface of the aluminum alloy.

If painting aggravates the heat absorption problem, the standard de-icing covers can be applied to shield the panels from the direct radiation of the sun. The covers may be acquired in a variety of colors or painted.

When painting is desired to improve appearances, but shielding of the face skin is adviseable, the following steps could be specified:

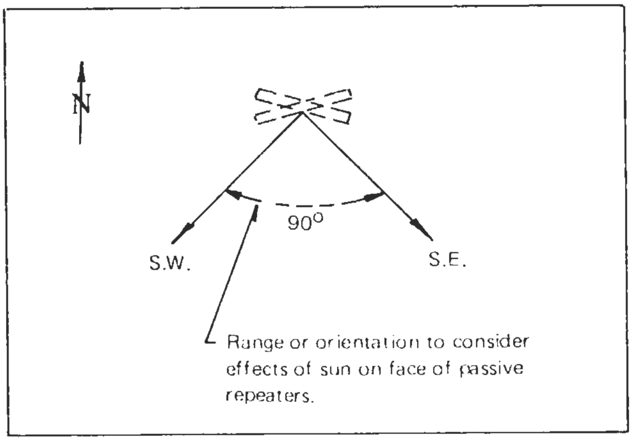
1. Paint the aluminum face skin with a special white paint to reduce heat absorption.
2. Install white covers to shield the face from the sun's radiation.
3. Paint the white covers a color that generally blends with the surrounding.
   (The covers could be shop or field painted.)

PAINTING TO REDUCE THE EFFECTS OF THE SUN'S RADIATION

When a passive repeater is oriented toward the southeast, the panel assembly may be frosted and near sub-zero temperatures very early in the morning. By mid-morning the face skin may be heated by the sun's radiation causing extreme temperature differentials between the front and back of the panel assembly. This may cause distortion of the face beyond accepted tolerances at high system frequencies (11 GHz) resulting in signal degradation ordinarily not considered in the system design. The distortion of the face may take the form of a gradual warping of the entire panel assembly along with a moderate ripple about the individual face skin stiffeners. No permanent deformation occurs.

It must be kept in mind that this type problem is not ordinary. However, the condition can be aggravated by the addition of dark, absorbing colors used for camouflage.

The figure below illustrates the range of passive repeater orientation that causes the greatest susceptibility to temperature differential problems. Conclusions that passives are restricted to the orientations not indicated by the figure must be avoided. In general large passive repeaters used for 11 GHz systems should be painted white when oriented in the directions shown by the figure.



Range or orientation to consider effects of sun on face of passive repeaters.

The best solution to the problem of temperature differentials, caused by the sun's radiation, is to paint the face skin with a special white paint to minimize the effects of the sun's radiation. In fact, this should be regarded as the only practical and economical solution of this problem for most installations, This technique is used frequently for large earth-station antennas. These

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* Anodizing of the aluminum panels is sometimes considered, but the costs usually outweigh the advantages. There also are too many chances that the surfaces will get scratched before the installation is complete.

antennas would not operate within specifications without the application of the white paint. Possible adverse appearances can be greatly exaggerated. The importance of proper operation and benefits in configuring microwave paths with passive repeaters should be emphasized to those concerned with appearances.

COVERING TO REDUCE THE EFFECTS OF ICING

Microflect Company has developed deicing kits for all Microflect passive repeater models. These are designed for either a shop installed addition or for field installation without alterations in shop processes. The covers are made from 18 ounce type ATV plastic-coated nylon fabric, and are fitted with a PVC pipe frame to space the fabric out from the reflecting surface. Black covers are supplied unless other colors or painting of covers is specified. The black covers are standard on Microflect arctic models.

The fabric cover does not prevent the buildup of ice but rather promotes the shedding of ice after a certain accumulation has occurred. The effectiveness of the covers depends upon the type and rapidity of the ice buildup, the action of the wind, and the radiation absorbed from the sun. It is not possible to predict the results in advance. However, these covers have been used with success, and the chances are good that their use will prevent serious outages due to ice accumulation. If only half the passive repeater is clear of ice, the received signal level will be down by 6 dB, which is usually tolerable under the usual stable path conditions in winter. The installation of the covers can be expected to reduce the passive repeater gain by about 0.5 dB for 6 GH$_z$ and about 1.0 dB for 11 GH$_z$.

CAMOUFLAGING

Camouflaging with variance of colors may seem effective when viewed from a particular range and position, but the distant view generally only yields a vague silhouette of the panel assembly without distinction in coloring. Minimizing the removal of small brush and trees in the vicinity of the passive probably causes the best camouflage effect. Adding covering to the support steel or adding irregular shapes adjacent to the passive generally adds to the size of the silhouette viewed and causes the close-in view to be worsened in appearance.

RECOMMENDATIONS FOR PAINTING, COVERING, AND CAMOUFLAGING

When anxieties arise about possible objections to a passive repeater's appearance, the first step is to evaluate just how serious the matter may be. This statement may seem trivial, but consider how the description of the unit in wording alone, may be the only problem or the beginning of the anxieties. Therefore, avoid the use of "billboard" reflector. Use "radio mirror" or "radio passive repeater", or anything that more accurately describes its function without being likened to advertising billboards. Meet with those that may object to appearances and describe the appearance and function, along with the appearances and physical disruption of alternate methods of establishing the communications facilities.

If painting is judged necessary, select a single color of flat paint. Be cautious of the possible effects of the sun's radiation with the application of dark colors. Elaborate multi-color camouflage schemes seldom yield the results desired for the effort and cost involved.

When painting is required to reduce the effects of the sun's radiation, paint the passive a flat white. Check with Microflect for a white paint that is applied in the shop.

In general, specify shop painting rather than field painting, and contact Microflect before final decision to paint is made, to discuss alternatives and extent of the painting.

Where objection is made to the appearnace of the white paint, try to convince those objecting of the necessity for performance.

Where attenuation due to ice accumulation is anticipated, specify Microflect's black de-icing covers.

When covers are needed to protect the surface from the sun's radiation, specify the aluminum surface painted white, and select the lightest color cover available and accepted for appearance. In some cases it may be desireable to specify a white cover that will be painted in the field.

In general, avoid camouflaging by attaching covering material to the supporting steel. The steel supporting the reflector is least visible in its standard galvanized state. Structures adjacent to the passive seldom enhance esthetics.

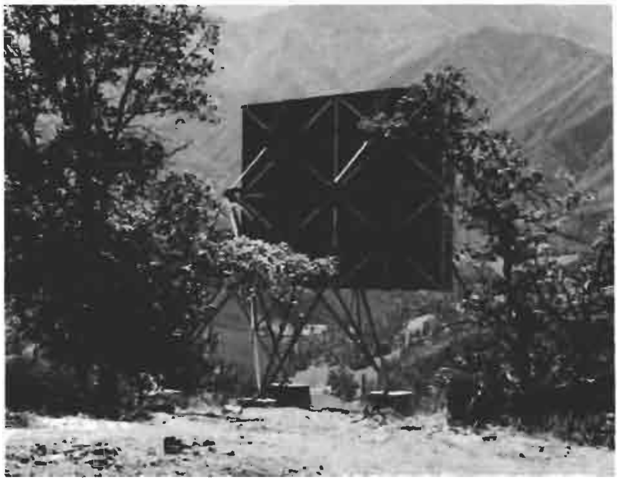
Landscaping with trees or brush that remain below the passive reflecting surface in front and raise as high as the reflector in the rear can minimize the awareness of the reflector to the casual eye. However, landscaping can be very costly and have dubious value with regard to the real environmental effect of the passive.

CONCLUDING REMARKS

It cannot be over-emphasized that Microflect standard passive repeaters usually cause no problems with respect to system performance.

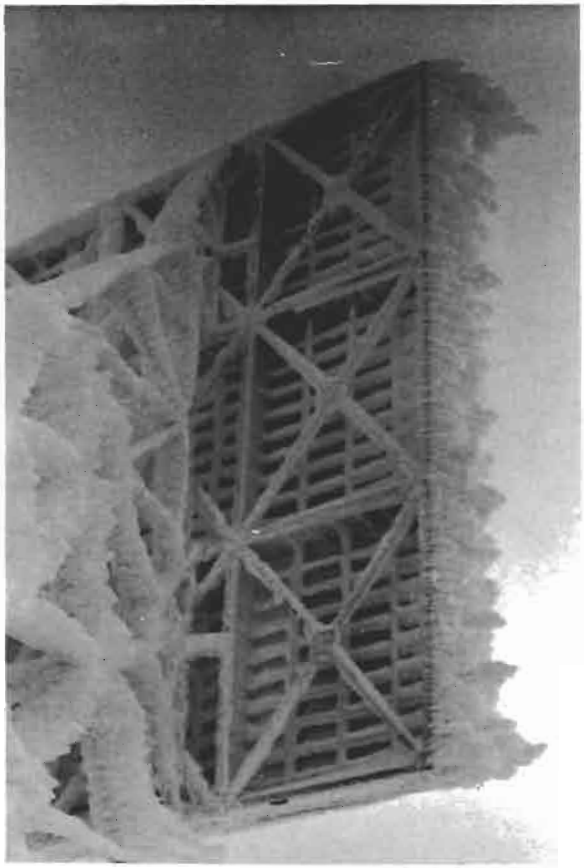
When temperature differential problems occur, the application of the right type of white paint on the face is the best solution, and logically should be regarded as the only practical and economical solution.

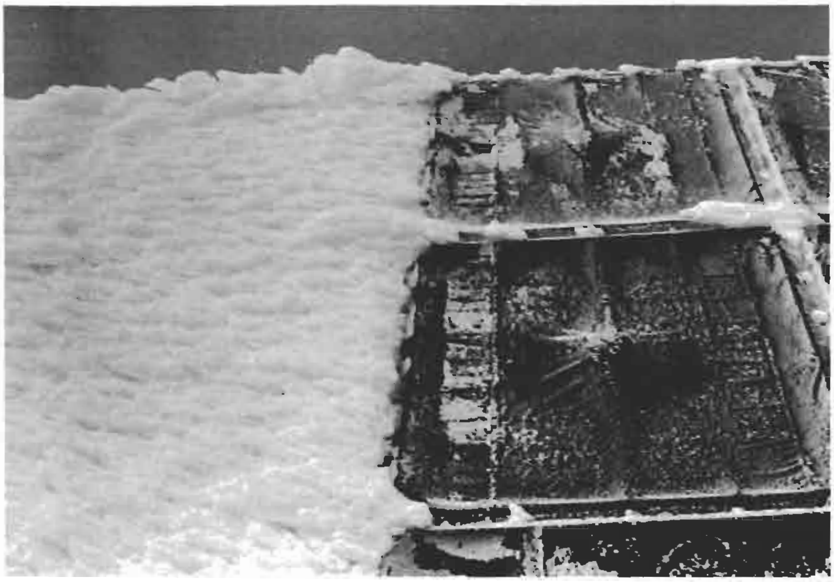
A complete study of the environmental impact of passive repeaters would definitely put the passive repeater in a favorable position. Consider the following photograph and associated ecological points made.



Ecological damage to our environment is becoming a major concren in the communications industry. The passive repeater is often a solution to these problems Advantages in terms of ecology are:

No noise or harmful radiation
Land requirements are small and need not be level
No aircraft obstruction lighting required.
The aluminum face reflects surrounding terrain for natural camouflaging effect.
Access can be accomplished with helicopters
They allow wider selection of sites during planning stages.
Razing of land for access roads and power lines is not required
Forest fire hazards are reduced since personnel access is reduced and no power is required.





These photographs demonstrate the effectiveness of Microflect's de-icing covers in a particular circumstance.

The passive repeater is a Microflect model 3048-15 installed at Chichagof in Alaska for a microwave link between Angoon and Wheeler for RCA Alascom.

All eighteen 8' x 10' panels were painted black but the southeast orientation of the passive minimized the heat absorption from the sun and several system outages resulted from ice accumulation.

The six center panels were covered in the summer of 1974 with the ATV plastic coated nylon fabric covers described in Microflect Bulletin No. 274. As a result of the apparent effectiveness of the six covers, a decision has been made to cover the remaining panels in 1975.

The covers were taut when installed in the summer. The slack appearance in these photographs results from the negative temperature coefficient which causes the material to expand as the temperature drops. The exact mechanism by which the covers shed ice is unknown. It is doubtless a combination of the texture of the material, the flexibility and wind action, the air space between the covers and the aluminum, and the expansion and contraction of the material with temperature changes.

It may be the covers are less effective than these photographs suggest when the ice forming conditions are different than those which occured in this instance.

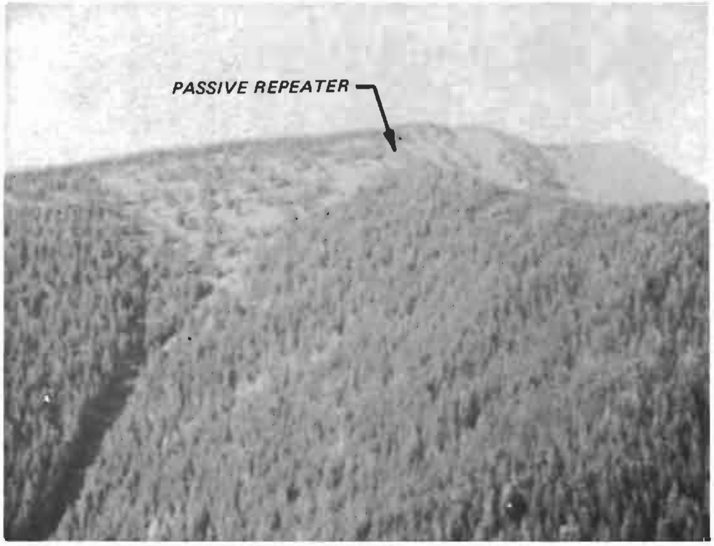
AERIAL VIEWS
OF PASSIVE REPEATER

This series of photographs illustrate how passive repeaters are inconspicuous in their typical application

Notice how little the environment is affected by the passive.

The series of photographs were taken at various distances from the site

From most positions the passive was not visible even though it was installed on a ridge in a reasonably large clearing in the trees.



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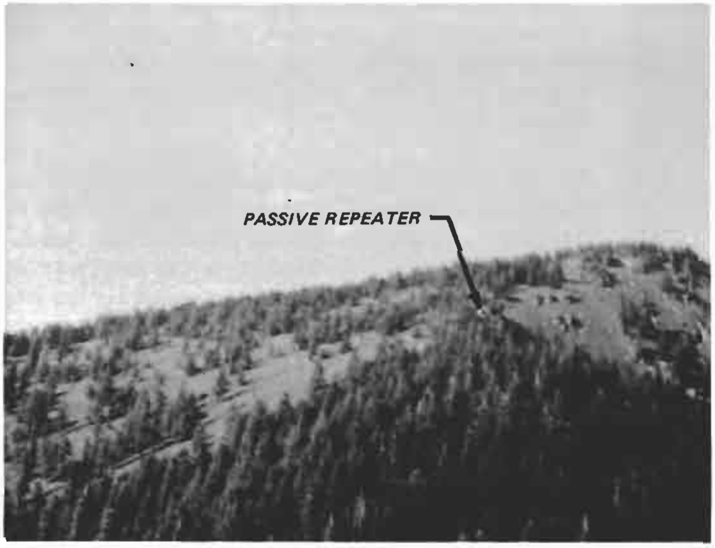

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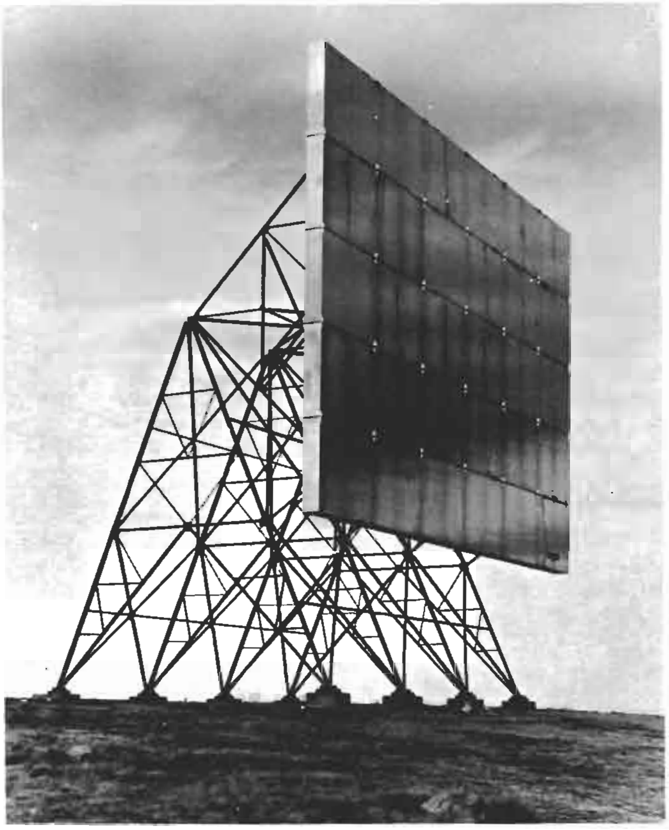
Notes

Notes

Appendix

GROUND MOUNTED PASSIVE REPEATERS



DESIGN

Microflect passive repeater design criteria is based on RS 222 C specifications, and designed for wind loads of 62.5 psf or the equivalent wind velocity of 125 mph.

REFLECTING FACE

Microflect passive repeaters are designed and manufactured to meet or exceed face flatness and rigidity requirements for 13 GHz operation. A system using a passive repeater with these specifications will not require future modification if a low frequency is changed to a higher one.

FACE ANGLE AND ADJUSTMENT

Each passive repeater is supplied with "K" members that are of proper length to suit the mechanical center of the adjustment range of a particular vertical face angle, (see drawing side views and "K" indication). Optimizing is accomplished manually by turning crank type mechanisms: 10 turns of vertical adjustment will rotate the the passive face 0° 25'30" vertically, and 10 turns of horizontal adjustment will rotate the passive face 0° 20'12" horizontally.* Adjustments are made quickly and easily for recording transmission data used in plotting the radiation pattern.

For face angles in excess of ten degrees downward , the limit of the "K" member is exceeded. In these instances, which are infrequent , the entire supporting structure is rotated forward by sloping the foundation piers.

* 24 x 30 Passive Repeater

ALLOWABLE STRESSES

In accordance with EIA Spec. RS 222C for steel and MIL–SPEC–5 for aluminum.

DESIGN LOADING

(a) 125 mph wind , no ice
(b) 100 mph wind , 2" of ice on one face
(c) 75 mph wind , 4" of ice on one face

RIGIDITY

All units are designed to meet rigidity requirements of EIA RS--195A for 13 GHz operation.

FACE FLATNESS

Under no load the face flatness will be plus 0" and minus 1/8" where negative values indicate a concave surface.

FACE DEFLECTION

Under 75 mph winds the deflection of the face stiffners will be less than 1/8" from the no load position.

ADJUSTABILITY

Units up to 30x48 have maximum adjusting ranges of ± 4° about either axis or ± 2° about both axes simultaneously. Sizes 40x50 and 40x60 have azimuth only ± 1°42', elevation only ± 2°33', combined azimuth ± 0°51' and elevation ± 1°16'.

CORROSION PROTECTION

All structural steel is galvanized after fabrication in accordance with ASTM A–123 for structural members and A--153 for hardware.

REFLECTING FACE

Reflecting face is 0.063 solid aluminum without perforation. All aluminum fabrication follows aircraft riveting standards.

TYPHOON MODELS

Typhoon models, based on 187 mph design (240 mph wind survival) are available for application in areas known to have severe wind conditions.

ARCTIC MODELS

Arctic passives are designed in accordance with E.I.A. Specification RS-222-C for the following loading conditions:

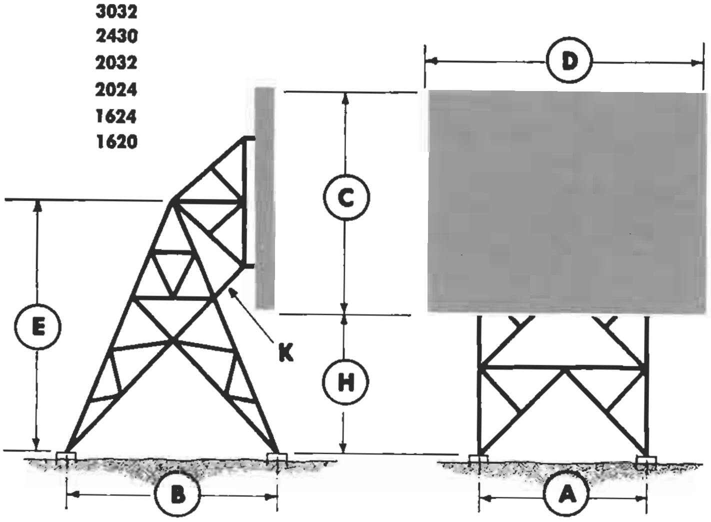
(a) 60 psf wind (122 mph) plus 4" of radial ice at 50 lbs/ft^3.
(b) 30 psf wind (86 mph) plus 12" of radial ice at 30 lbs/ft^3.

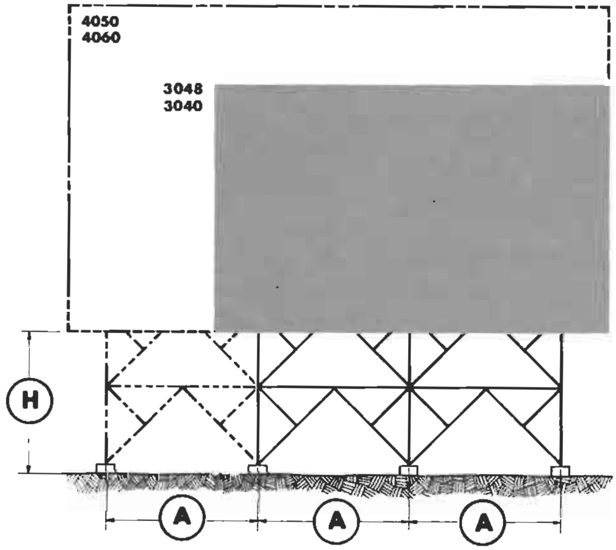
The reflecting surface of the Arctic Passives will remain in position within ± 0.25° under loading (a) or (b) above.

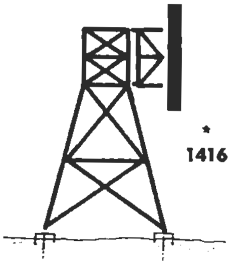
ERECTION

Hinged shoe plates allow a complete side, that has been assembled on the ground, to be tipped up into position by a simple hand winch or a vehicle power winch. Panels assembled in horizontal tiers are lifted into position by the use of outriggers at the top of each frame station. Erection drawings are supplied with each passive repeater for fast, safe erection.

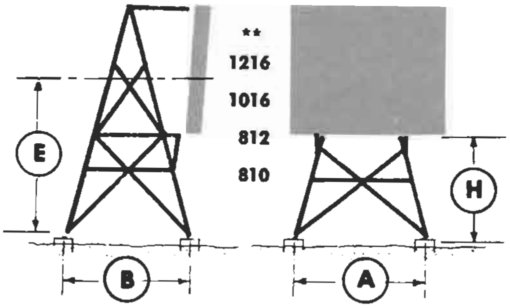
Helicopters are used for remote inaccessible site installation. The aluminum panels weigh 270 pounds each. A helicopter is normally capable of transporting two panels each trip. The maximum length of structural steel is 20 feet and is transported easily.







* Three legged configuration



** Four legged pyramid configuration

H 8' GROUND CLEARANCE

Model	No. of Frames	A Ft.-In.	B Ft.-In.	C Feet	D Feet	E Ft.-In.
3048-8	3	16-0	19-2	30	48	23-0
3040-8	3	14-0	19-2	30	40	23-0
3032-8	2	18-3	19-2	30	32	23-0
2430-8	2	18-0	16-8	24	30	20-0
2032-8	2	16-0	15-0	20	32	18-0
2024-8	2	16-0	15-0	20	24	18-0
1624-8	2	12-0	13-4	16	24	16-0
1620-8	2	12-0	13-4	16	20	16-0
1416-8	*	11-0	9-6	14	16	15-0
1216-8	**	10-0	10-0	12	16	14-5
1016-8	**	10-0	10-0	10	16	13-5
812-8	**	8-9	8-9	8	12	12-0
810-8	**	8-9	8-9	8	10	12-0

H 15' GROUND CLEARANCE

Model	No. of Frames	A Ft.-In.	B Ft.-In.	C Feet	D Feet	E Ft.-In.
4060-15	4	15-0	29-2	40	60	35-0
4050-15	4	15-0	29-2	40	50	35-0
3048-15	3	16-0	25-0	30	48	30-0
3040-15	3	14-0	25-0	30	40	30-0
3032-15	2	18-3	25-0	30	32	30-0
2430-15	2	18-0	22-6	24	30	27-0
2032-15	2	16-0	20-10	20	32	25-0
2024-15	2	16-0	20-10	20	24	25-0
1624-15	2	12-0	19-2	16	24	23-0
1620-15	2	12-0	19-2	16	20	23-0
1416-15	*	14-0	12-1½	14	16	22-0
1216-15	**	13-5	13-5	12	16	21-0
1016-15	**	13-5	13-5	10	16	20-0
812-15	**	12-5	12-5	8	12	19-0
810-15	**	12-5	12-5	8	10	19-0

** Three legged configuration*
*** Four legged configuration*

WALL AND TOWER MOUNTED PASSIVE REPEATERS

Microflect's wall and tower mounted rectangular passive repeaters have been designed in accordance with EIA specification RS-222C for 100 mph winds (40 psf) coincident with ½" radial ice. Face flatness and rigidity meet 13 GHz requirements as specified in RS-195A.

The reflecting panels are made with 6061-T6 and 6063-T6 aluminum alloys for superior strength characteristics and corrosion resistance. The supporting structure is steel, galvanized in accordance with ASTM A-123 and A-153 (for hardware).

Each unit is complete with all supporting members, adjusting arms, interface steel, and hardware as shown on the drawings. The through bolts for attaching the structure to the wall are not included because the requirements vary widely with wall details.

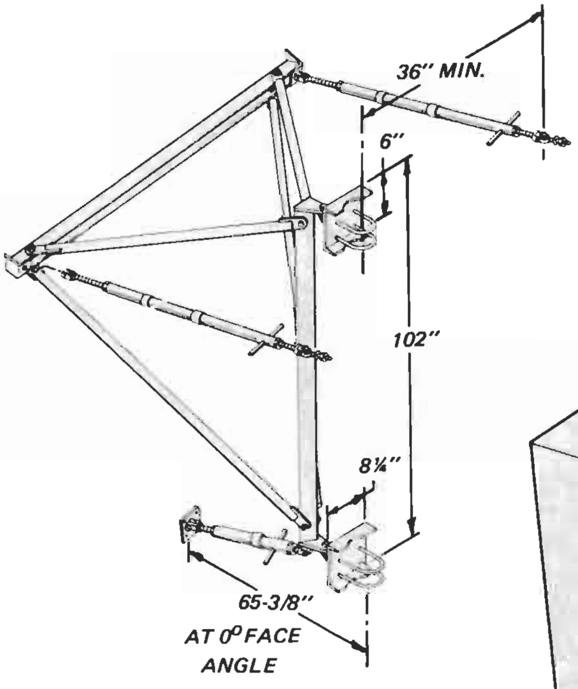
If the standard configurations shown do not fit your particular requirement, please provide the necessary details and we will design a modification to meet your specifications.

Larger sizes, 16x20 and up, may also be wall mounted but each structure is designed for the particular application.

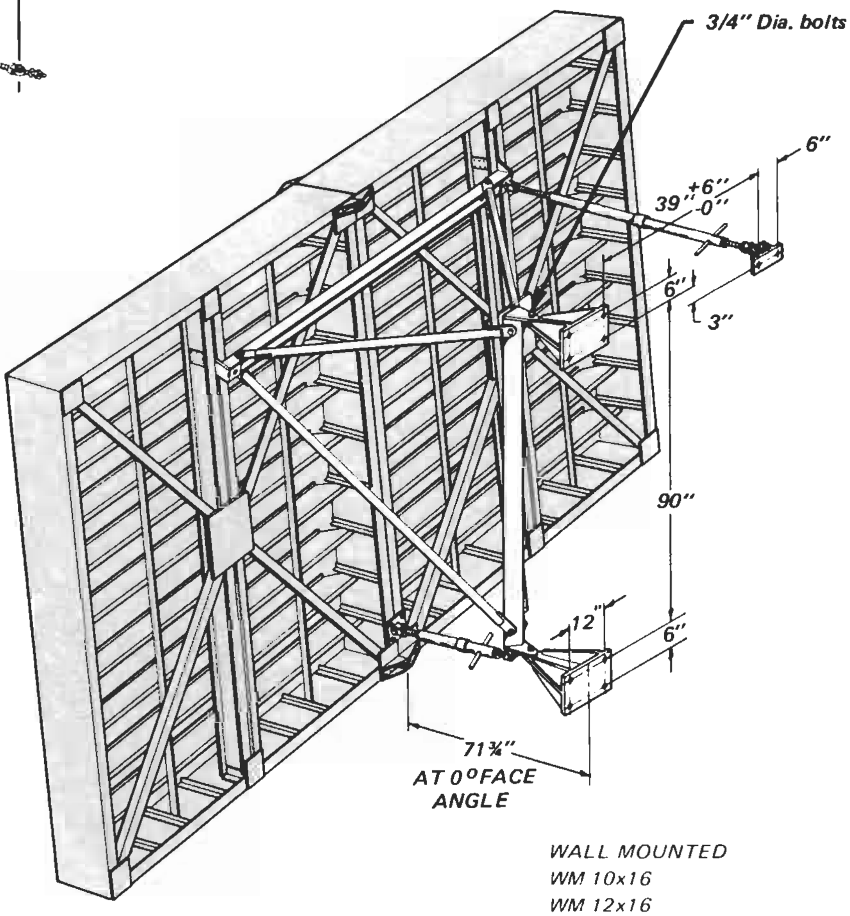
The passives may be painted to blend with the background without affecting the reflecting properties of the units.

18 GHz passive repeaters available (except 1416) on special order. Face flatness held to closer tolerance, two azimuth rods included and panels painted white to minimize thermal distortion.

All mounting holes on wall brackets are 13/16" diameter for 5/8" diameter mounting bolts.

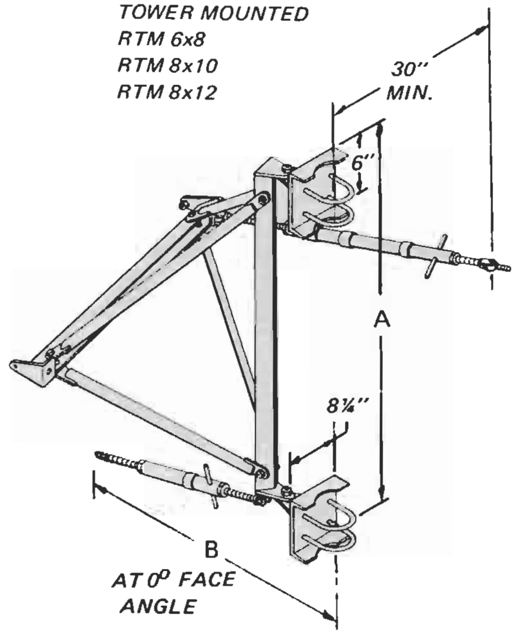


TOWER MOUNTED
RTM 10x16
RTM 12x16

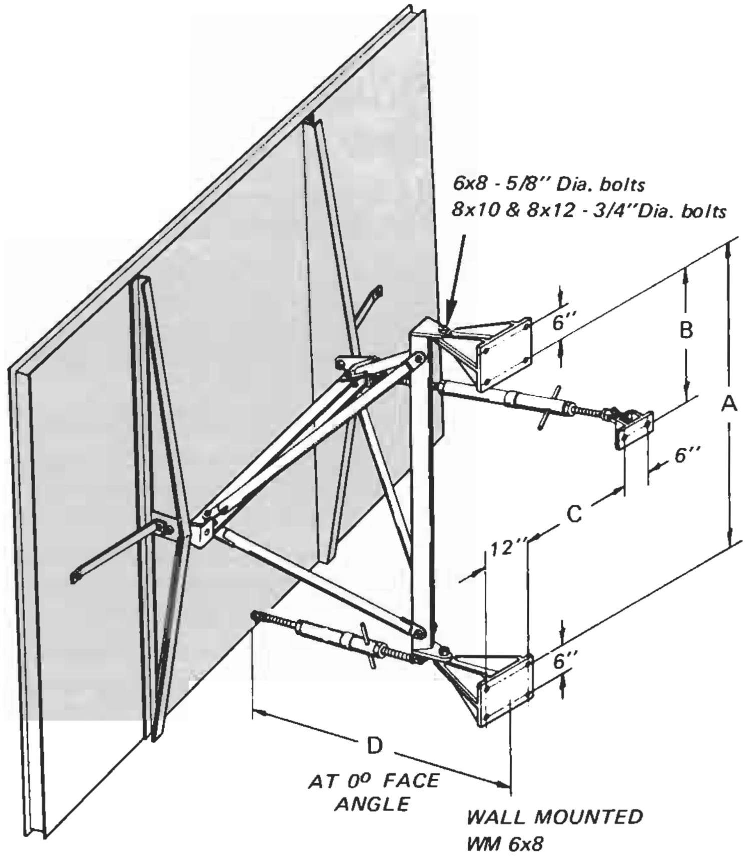


WALL MOUNTED
WM 10x16
WM 12x16

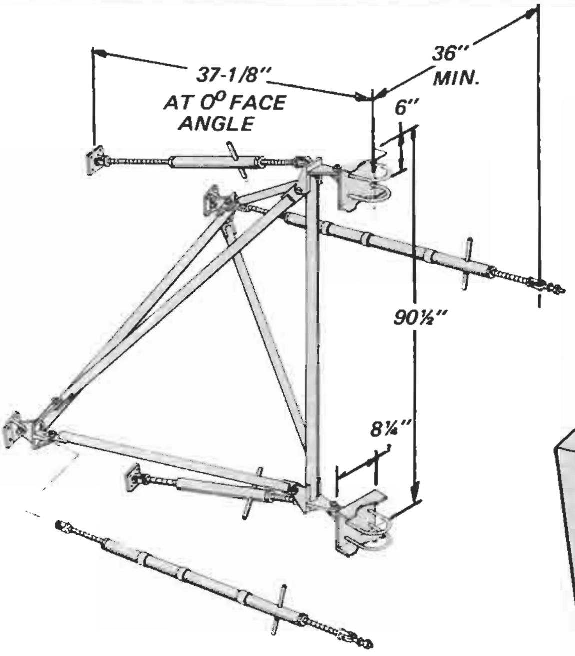
TOWER MOUNTED
RTM 6x8
RTM 8x10
RTM 8x12



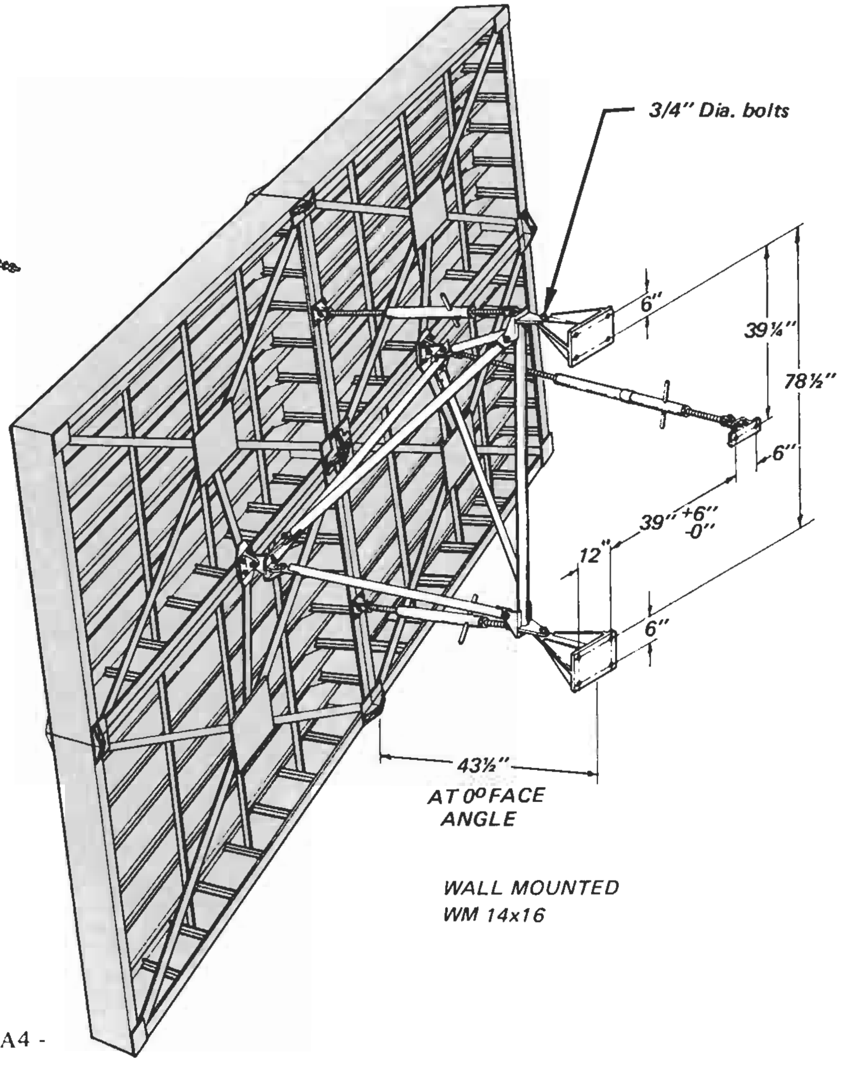
Model	Tower Mounted		Wall Mounted			
	A	B	A	B	C $^{+6''}_{-0''}$	D
6x8	46½"	47-1/8"	34⅜"	17¼"	15"	53½"
8x10	90"	48-5/8"	78"	39"	27"	55"
8x12	90"	48-5/8"	78"	39"	27"	55"



WALL MOUNTED
WM 6x8
WM 8x10
WM 8x12



TOWER MOUNTED
RTM 14x16



WALL MOUNTED
WM 14x16

Wall Mounted Passive Repeaters

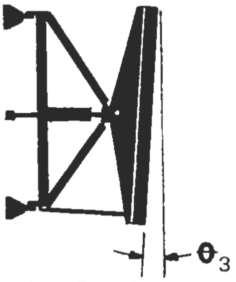
OPTIMIZING

Azimuth and elevation adjustments may be made by rotating the appropriate adjusting handles. Refer to adjusting procedures shown on the assembly drawings which are included with each shipment and may be found in the hardware box. Azimuth and elevation adjusting limits are at least ±5° about the calculated normal position.

The maximum angle of the passive, relative to the wall, is limited by the particular face angle for that installation. Refer to the following chart for angular limits. The chart allows for an additional adjustment of 5° in azimuth and elevation.

	θ					
θ_3	6x8 *	8x10	8x12	10x16	12x16	14x16
0	46°00′	40°30′	35°00′	35°00′	35°00′	22°00′
4°	44°15′	38°30′	33°00′	31°45′	31°30′	19°00′
8°	42°30′	36°00′	31°00′	28°30′	27°30′	15°30′
12°	40°30′	33°45′	28°45′	25°00′	23°45′	12°15′
16°	38°45′	31°00′	26°30′	21°30′	19°30′	---
20°	36°45′	28°15′	24°00′	---	---	---

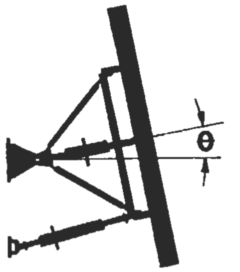
* *Sizes are in feet.*



Side Elevation

MOUNTING

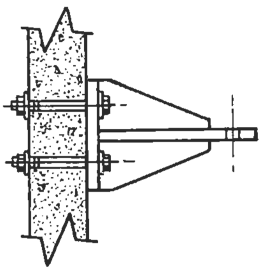
The method of attaching the brackets to the wall will of course depend upon the details of construction encountered. It is necessary to secure the units to a portion of a wall or a structure that will not allow deflection of the passive structure. The vertical bolt spacing cannot be varied but the location of the azimuth rod attaching point can be varied horizontally to accomodate the structural details of the wall. The horizontal dimension, shown between the center line and the azimuth rod attachment, should be considered minimum. Note that the azimuth rod can be mounted on either the left or right side to meet the requirements of the passive bearing.



Plan View

ORDERING

Specify size, face angle θ_3, and relative angle between the wall and the passive, θ. The length and range of azimuth and elevation rods will be supplied to accomodate the design angles, θ and θ_3 and provide ± 5° of adjustment. We will calculate the face angle if you provide the horizontal included angle and both vertical path angles. Include shipping instructions and other pertinent data.



Typical Mounting

Tower Mounted Passive Repeaters

OPTIMIZING

The RTM series of passive repeaters are supplied with clamps to attach directly to a 4½" OD pipe. The minimum length of pipe which is required for each size is shown elsewhere in this catalog. The pipe is not included with the passive.

Location of the pipe mount on the tower should be done with consideration given to the required azimuth angle for the passive. In addition, it is important that the passive be located so a satisfactory support point is available for the azimuth rod attachment.

The most important and the most difficult part of any reflector installation is the proper location for the attachment of the azimuth rod. The more wide spread the rod can be placed, the more rigid the installation. The rod end requires an 11/16 inch diameter hole with a maximum grip of 3/8 inches. The rod end should be mounted with its axis approximately parallel to the axis of the rod... as nearly so as possible. Avoid a 90° connection such as you would have if the rod end were installed in the horizonal leg of a girt. This connection would be satisfactory if the azimuth rod more or less parallels the girt, but not if the rod were at right angles to the girt.

MOUNTING

The best spot to connect the azimuth rods would be on the tower leg as close as possible to a diagonal or girt connection. A rigid strong point of the tower must be selected for this connection.
The length of the azimuth adjusting rod can be varied by removing sections of the rod at the couplings. Determine the required length before the reflector is raised and mounted. See table below.

AZIMUTH ROD ADJUSTMENT LENGTH (Inches)

	6 x 8	8 x 10	8 x 12	10 x 16	12 x 16	14 x 16
Min.	29	48	48	48	48	48
Max.	88	150	150	150	150	150

The 10x16, 12x16, and 14x16 sizes have two azimuth rods. The three smaller sizes have one.

ORDERING

Specify design vertical face angle so that the proper length elevation rod can be supplied to make available plus or minus five degrees about the neutral position.

	6 x 8	8 x 10	8 x 12	10 x 16	12 x 16	14 x 16
Domestic Shipping Wt. (Lbs)	400	705	745	1,075	1,215	1,295
Export Crated Wt. (Lbs)	520	995	1,035	1,385	1,575	1,650
Export Crated Cube (Cu. Ft.)	41	80	94	282	333	383

Specifications

DESIGN LOADING

(a) 125 mph wind (62.5 psf), no ice

(b) 100 mph wind (40 psf), 2" of ice

(c) 75 mph wind(22.5 psf), 4" of ice.

(d) 35 mph wind (5psf), 9" of ice.

ALLOWABLE STRESSES

In accordance with EIA Spec. RS 222 C
RIGIDITY:
For 13 GHz as per EIA Spec. RS-195-A

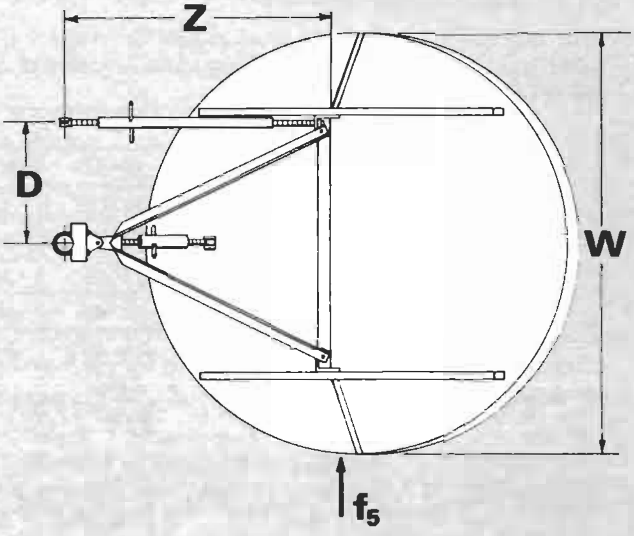
FACE FLATNESS

Under no load the face flatness will be plus 0" and minus .10" where negative values indicate a concave surface.

MATERIAL

All structural steel is galvanized after fabrication in accordance with ASTM A-123 for structural members, and A-153 for hardware. Reflecting face is 0.063" solid aluminum without perforations. All aluminum fabrication conforms to aircraft riveting standards.

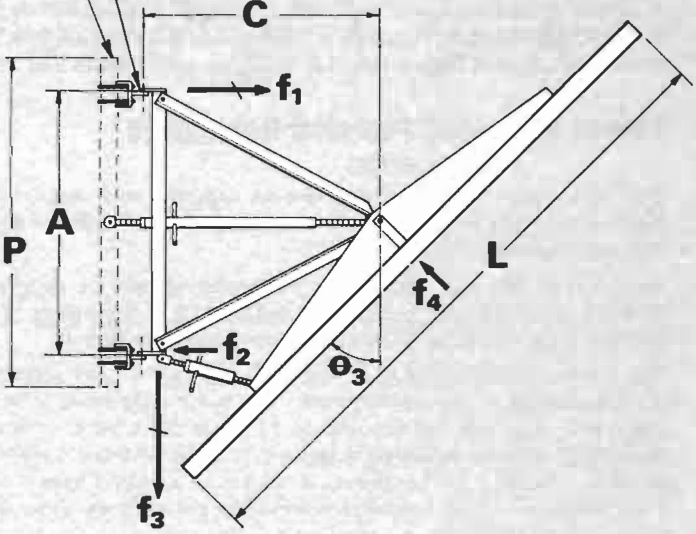
Key Dimensions



PLAN VIEW

Pipe and pipe mounting brackets must be ordered separately

"B" DIMENSION IS THICKNESS OF MOUNTING PLATE.



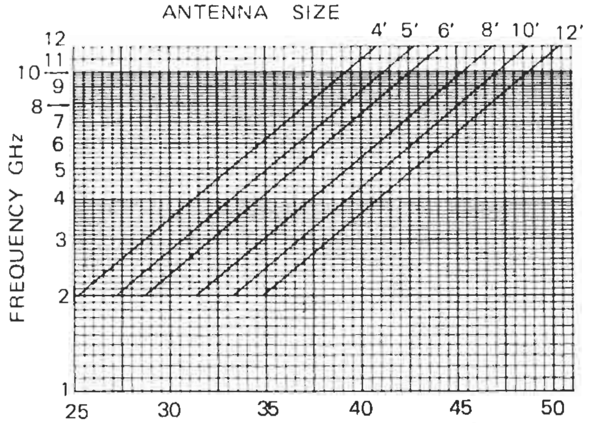
LOADS AND REACTIONS, LBS. 125 mph WIND					
REFLECTOR SIZE	f1	f2	f3	f4	f5
4′ x 6′	920	330	590	840	280
6′ x 8′	1650	475	1175	1660	375
8′ x 12′	3300	950	2350	3340	680
10′ x 15′	4600	950	3650	5200	980
12′ x 17′	6700	1700	5000	7070	1450

NOTE—REVERSE DIRECTION OF FORCES FOR WIND FROM REAR

REFLECTOR MODEL No.	REFLECTOR SIZE W x L	A (inches)	B (inches)	C (inches)	θ_3 Max. (degrees)	θ_3 Min. (degrees)	AZ. ROD (Z) ** Max. (inches)	AZ. ROD (Z) ** Min. (inches)	D Min. (inches)	P * MINIMUM PIPE LENGTH	WEIGHTS (lbs.) NET	WEIGHTS (lbs.) CRATED	WEIGHTS (lbs.) EXPORT	CUBE
TM-46	4 x 6	30	3/8	32	50	32	108	50	13	36	160	185	200	23
TM-68	6 x 8	40	3/8	36	48	34	108	50	21	46	220	265	290	36
TM-812	8 x 12	59½	½	54	52	30	150	74	27	66	420	520	545	62
TM-1015	10 x 15	83½	½	64	52	30	150	74	30	90	580	755	790	117
TM-1217	12 x 17	95¼	¾	80	52	30	150	74	30	102	890	1140	1180	147

* Not Part of Reflector

** One required, except Model TM-1217, which requires 2.



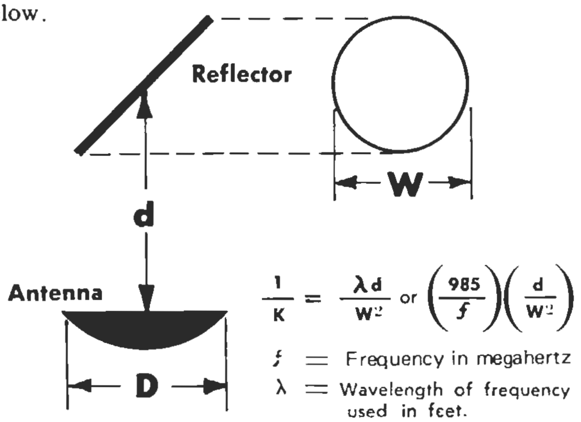
GAIN "G" IN dB = 10 LOG $\frac{5\,D^2}{\lambda^2}$

Figure 1

TABLES and CURVES for DETERMINATION of ANTENNA-REFLECTOR SYSTEM GAIN

The performance of an antenna-reflector periscope system is a function of: (a) System frequency (b) Antenna-reflector spacing (c) Antenna diameter, and (d) Reflector size.

Figures 1 and 2, can be used to calculate the gain from any periscope-antenna system. If the values used do not fall within the curve limits, the value of 1/K must be calculated using the formula and diagram below.



$$\frac{1}{K} = \frac{\lambda d}{W^2} \text{ or } \left(\frac{985}{f}\right)\left(\frac{d}{W^2}\right)$$

f = Frequency in megahertz

λ = Wavelength of frequency used in feet.

Using the calculated value of 1/K, enter figure 2 at the bottom, (ignoring the frequency curve) and go directly up to the correct "ℓ" curve.

A 1/K value less than 0.15 is not recommended for "ℓ" values less than 0.6.

Directions for the Use of Tables and Curves

(1) Calculate the value for "ℓ". $\ell = \frac{D}{W}$

(2) Determine the antenna gain value "G" from figure 1.

(3) Enter figure 2 with the antenna-reflector spacing, up to the proper reflector size, left to the system frequency, upward to the appropriate "ℓ" curve, and finally left to read the value for α n.

(4) Add G to α n for the gain of the antenna-reflector combination.

Example: 11 GHz system, 100' spacing, 10' antenna, 10' x 15' reflector.

(a) "ℓ" = 1.0 (from step 1 above)

(b) "G" = +48 dB (from figure 1)

(c) α n = –1 dB (from figure 2)

(d) Net gain = +48 –1 = +47 dB

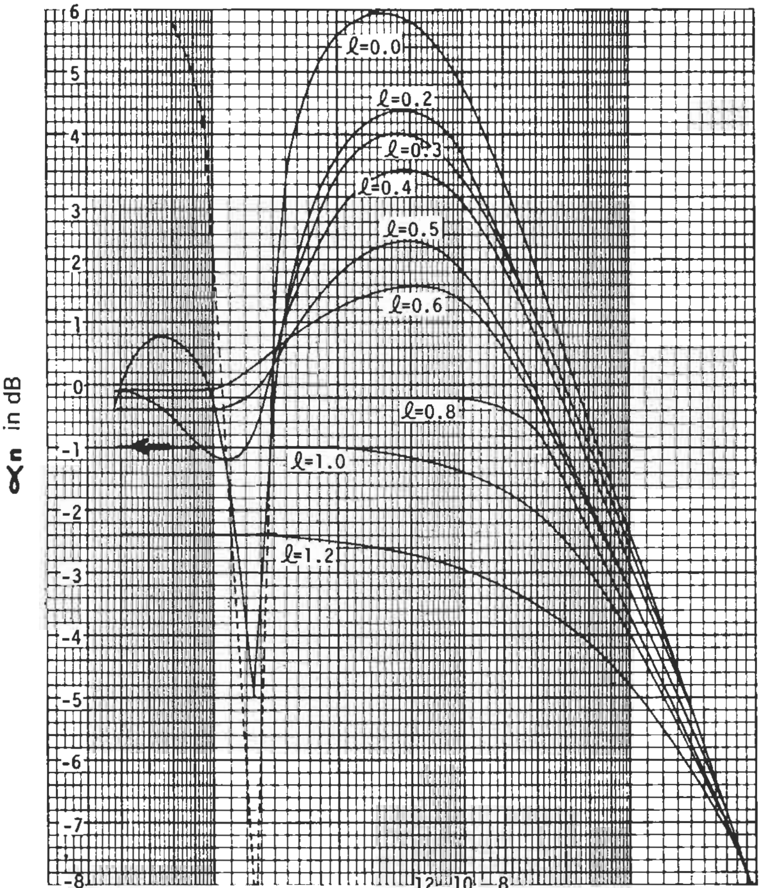
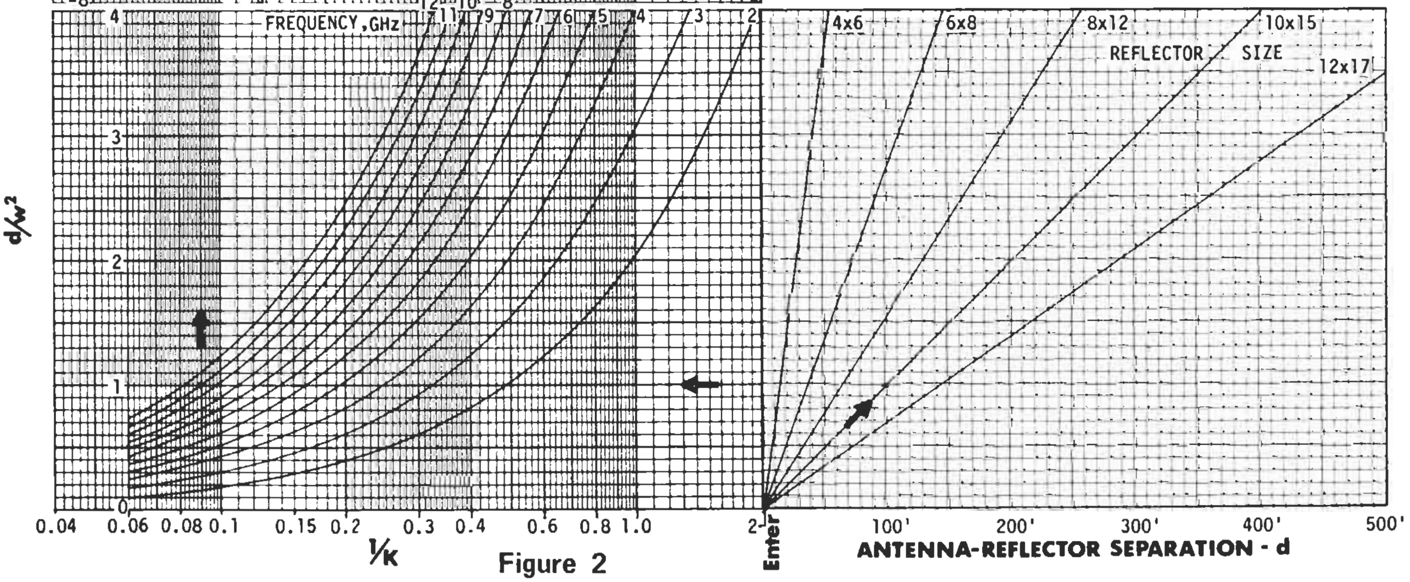



Figure 2

The large physical size of the 40 x 50 and 40 x 60 Passive Repeaters, with the twelve adjustable support points, combine to dictate a special adjusting procedure, as compared with that used for smaller passives. When adjusting the smaller passives, it is not unusual to scan, both horizontally and vertically, through one or more side lobes, and finally set the passive for maximum AGC reading. Scanning the 40 x 50 or 40 x 60 passives is not recommended and should not be attempted.

Instead, the following procedure has been developed which, if correctly done, will result in the proper setting with the least aggravation and expenditure of time and effort. The "proper" setting requires that the reflecting surface be (1) normal to the passive repeater bearing in the horizontal plane, (2) set at the correct vertical face angle, and (3) flat within 1/8" over the entire reflecting surface.

The method outlined herein accomplishes the three objectives simultaneously, which eliminates the risk of having one step destroy the results of a previous effort. The procedure breaks down into three phases, as follows:

(1) Establish a base line normal to the passive repeater bearing in a horizontal plane.
(2) Installation of probes on the face of the passive and locating targets on the probes.
(3) Positioning the passive repeater face so the targets on the probes lie in the vertical plane determined by the base line.

Before getting into the details of the work involved, it would be well to establish a firm understanding of the accuracy required to produce the desired result. The beam width, between half power points for a 40 x 60 passive operating at 2 or 6 GHz, is shown in Figure 1. A 90° included horizontal angle, between paths, is assumed to make the vertical and horizontal beamwidth the same. It appears that an accuracy of ± 0° 02' of arc would result in a setting that would be well within half a dB of the maximum theoretical gain position. This represents a variation of ± 0.42 inches from one end of the passive to the other; a variation of ±0.28 inches between the top and the bottom of the passive; a variation of three feet in a mile; fifteen feet in five miles; ninety - two feet in thirty miles, and so forth. This degree of accuracy implies the careful use of a quality transit, stakes with surveyor's tacks, multiple instrument readings, careful job planning, and unhurried execution of the work. Perhaps the most difficult requirement is being able to sight the terminal antennas with a transit from the passive site.

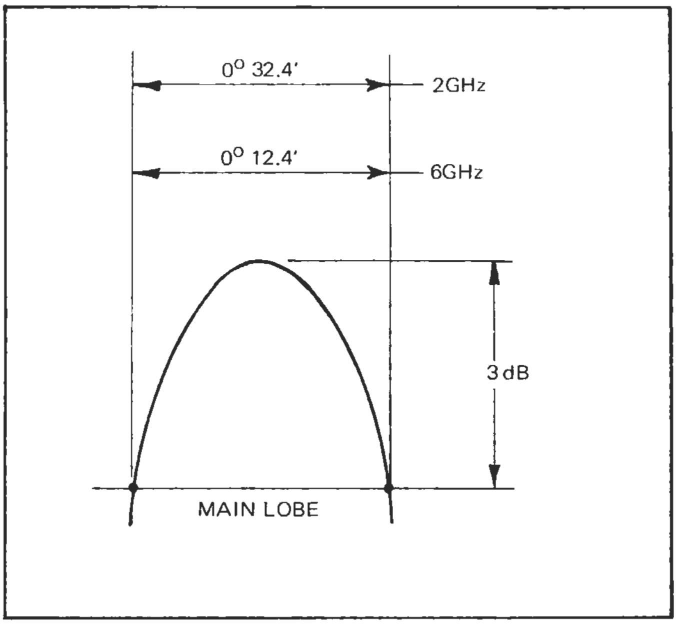


FIGURE 1. Passive Repeater Beamwidth

PHASE I

A passive repeater is properly set with the normal to the center of the passive bisecting the true angle between the paths from the two terminal antennas which intersect at the passive. Since the plane which includes the two paths is skewed, relative to a level plane, it is necessary to break this down into its components which are referenced to a vertical and horizontal plane. This is logical since a transit works in both a horizontal and vertical plane, but not in a skewed plane.

1.0 (See Figure 2, Step A and Figure 6)

Set a stake and tack on the center line of the passive and in front or behind the top edge of the passive face as shown in Figure 6.

This becomes the hub about which most of the work will be done, therefore set it securely and protect it from accidental damage. Set the transit up over the tack and estimate or measure the vertical distance between the center of the passive and the scope to the nearest foot. This will be about thirty feet.

1.1 (See Figure 2, Step B)

Sight on the nearest antenna along the vertical centerline and the same distance below the center of the antenna as the scope is below the center of the passive. You can either set a target on the antenna tower or estimate this vertical offset by comparing it with the size of the antenna. If it is a 10' antenna, you would look three diameters below the center; if it is a 15' antenna, sight two diameters below the center. This is assuming a thirty foot offset. The object is to have the transit sighting exactly parallel to the line connecting the center of the passive with the center of the antenna.

1.2

Set the transit table to zero. Read and record the vertical angle to the nearest minute of arc, and note whether up or down. Set a stake and tack on path about thirty or forty feet from the transit. Mark the vertical angle on the stake.

1.3

Rotate the transit and sight below the distant antenna an estimated amount equal to the distance the scope is below the passive centerline. With the distant antenna over ten miles away, this correction becomes of no practical importance. Sighting the distant antenna is often made difficult by the existence of haze and other obstructions to clear vision. Flashing the path with a large plate glass mirror is

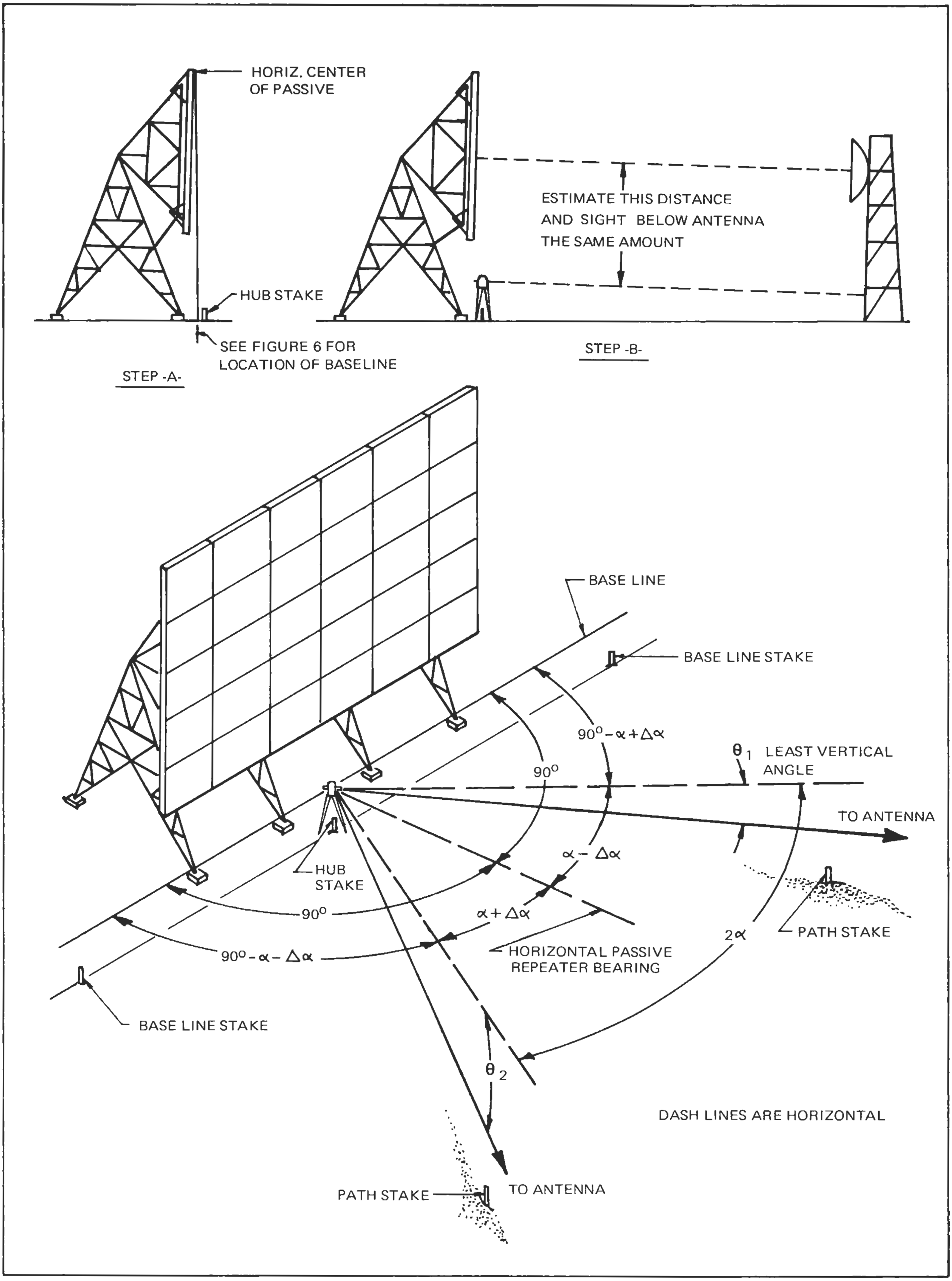


FIGURE 2. Baseline Calculations

often successful. In any case, it must be done and planning to take advantage of the opportunity presented by a clear day is well advised.

1.4

With the scope set on (or below) the antenna, record the vertical angle, noting whether up or down, and also record the included horizontal angle between paths. Read to the nearest minute of arc. Set a stake and tack on path about thirty or forty feet from the transit. Record the vertical angle on the stake.

Note: Up to this point, three stakes have been set and three angles recorded. This portion of the work can be done as a separate project, taking advantage of clear weather and making use of a qualified surveyor. The remaining part could be done with a crew selected for their ability to work with the passive and make the necessary calculations and adjustments.

2.0

Using the face angle calculation sheet, (page 67) enter the values for 2α , the horizontal included angle, and Θ_1 and Θ_2 which are the vertical path angles. Call the path with the least vertical angle Θ_1 . The angles should be entered to the nearest minute of arc and the trig functions carried out to five places. Calculate the horizontal correction angle $\Delta\alpha$, and the vertical face angle Θ_3 .

2.1

Establish the base line normal to the passive bearing by calculating the values for $90^\circ - \alpha + \Delta\alpha$ and $90^\circ - \alpha - \Delta\alpha$ as shown in Figure 2. Note that the passive repeater bearing need not be located with a stake. Also, note that always rotates the passive repeater bearing in the direction of the path with the least vertical angle, either up or down. Check the lay - out by confirming that the three stakes making up the base line form a straight line. Phase I is now completed and should be checked very carefully for accuracy before proceeding with Phase II.

PHASE II

The installation of probes and targets on the face of the passive repeater provides a convenient method of referencing the reflector face to a vertical plane. In this case, the vertical plane will pass through the base line which has been established normal to the horizontal passive repeater bearing. Twelve probes will be used to locate the passive bearing and vertical face angle, and to assure that the reflecting face is flat.

The probes consist of stainless steel rods, 3/8" in diameter, fully threaded, with suitable nuts, washers and couplers. The rods pass through the space between panels so no holes need be drilled. It is important that the spacing, top to bottom, be accurate and that the probes are normal to the face and do not sag down. When locating the top row of of probes, measure down from the lower side of the forging and then reference each succeeding row from the row above.

3.0 (See Figures 3 and 6)

Install the probes as shown in Figure 3 and 6, using a washer and nut on both sides of the panel. Make sure the probe is 90° to the face of the reflector and the proper distance down as shown. Leave the two target nuts loose near the outer end of the probe.

3.1

With the probes in place, set the transit, equipped with a 90° eyepiece, up over either end stake on the base line. Line the transit up carefully on the tack on the stake on the far end of the base line, making certain the transit is perfectly leveled. As the transit is rotated upward, the vertical crosshair will sweep through a vertical plane which intersects the base line.

3.2

Look through the transit at each of the twelve probes and make certain none are hidden behind another and that they are all long enough to project into sight and past the vertical crosshair. Select any "one" of the top probes and lock the double nuts together so the vertical crosshair passes through the mating surface between the two nuts. Set the target on only "one" of the probes in this manner.

3.3

Measure the distance from the face of the reflector to the target and set the other three targets on the top row of probes the exact same distance from the face of the passive.

3.4

Refer to the face angle calculation sheet and record the tangent of Θ_3 and multiply it by 140", which is the distance down to the next row of probes. Add the result to the measurement of the top row of targets from the face. This is the distance that the second row of targets should be located from the face. Now set the targets on the bottom row out from the face a distance equal to the product of 140 times the tangents of Θ_3 plus the distance out to the target on the center row. See Figure 4. At this point it is well to check and make certain that all of the above has been done correctly and accurately.

Note: It is important that only "one" of the targets is set on the crosshair and the other eleven are set by measuring to the face of the reflector.

The adjusting mechanisms for the 40 x 50 and 40 x 60 Passive Repeaters are identical. See Figure 5. There are twelve pairs of brackets with associated hardware that make up twelve adjustable supporting points for the reflector face. The adjustment feature consists of a leadscrew (which is fixed) and two nuts which are rotated to produce fore and aft motion of the reflector. Two lockbolts, with 1/2" spacers, provide additional security and are re - installed after the adjustment is complete.

If the leadscrews are equipped with handles, loosen the leadscrew nuts on each side of the vertical channel member and rotate the handle for adjustment. Lockbolts and ½" spacers must be removed during adjustment. When the lockbolts are removed the vertical weight of the panels is taken by the adjustable tension rods (8 total). These must be adjusted to remove the weight from the leadscrews and the lockbolts to avoid binding during adjustment and to allow the lockbolts to be removed and installed easily. Proper adjustment of these tension rods will save time and temper during the entire adjusting procedure and is well worth the effort.

Removal and replacement of the locking bolts may not be necessary at any or all of the adjustment points. If the tension rods are properly set and the distance to move is small, it may be best to loosen both lockbolts and tap them with a hammer to make them follow as the point is moved. However, if the joint is tight and binding up, it will be necessary to remove the lockbolts and ½" spacers completely.

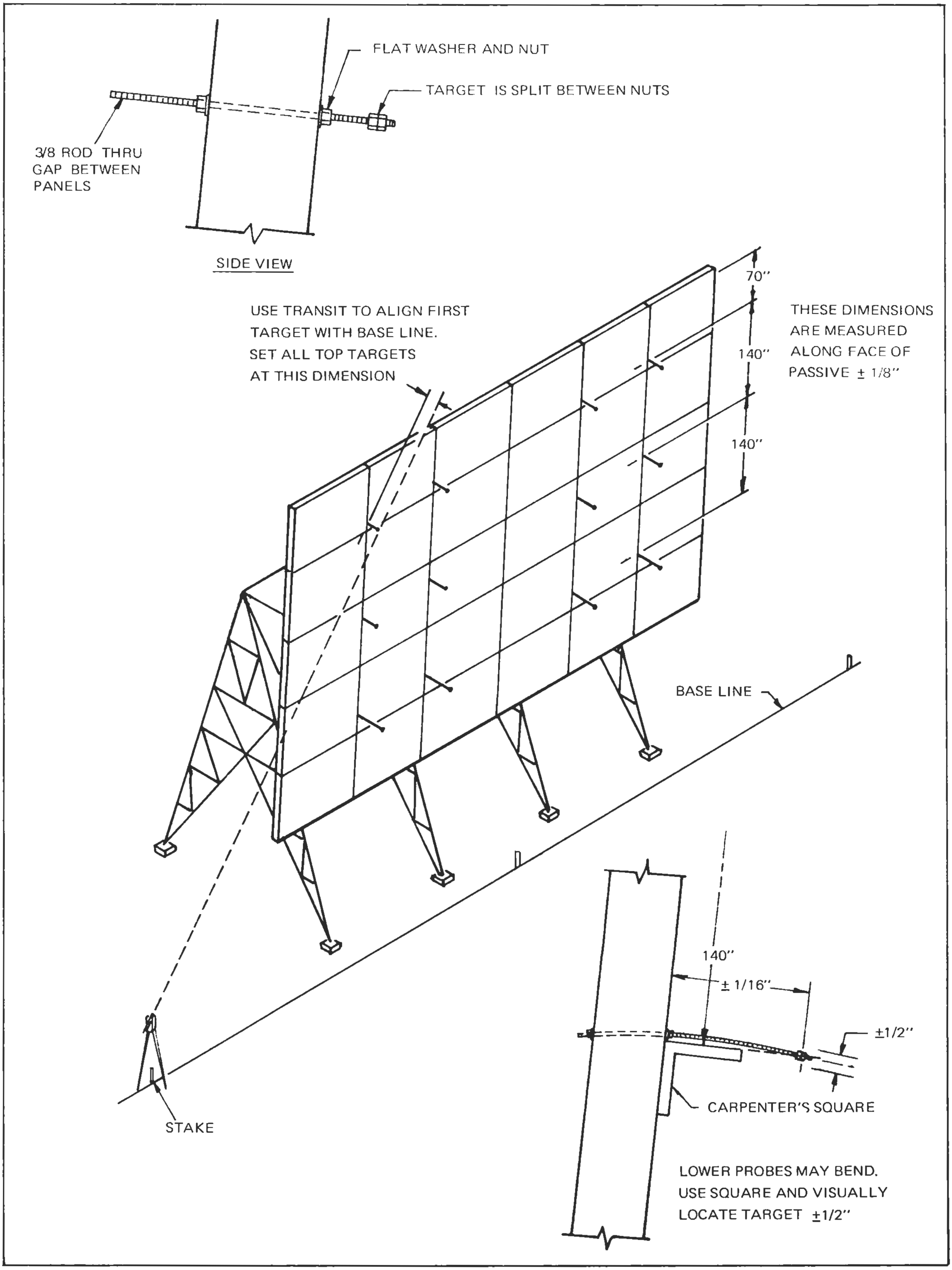


FIGURE 3. Installation of Target Probes

If the passive was ordered with the correct face angle and if the foundations are correctly oriented, the reflector should be within two inches or so of the final position.

4.0

Set the transit up over the baseline as in Paragraph 3.1. Move each adjusting point as required to line up the target with the vertical crosshair. This will involve progressive movement of successive adjustment points so that the entire reflector will swing into place without binding or forcing any particular adjustment.

4.1

When all targets are on the vertical crosshair, start locking down the adjusting mechanisms by installing and tightening the locking bolts and finally tightening the nuts on the leadscrew. Bring up the leadscrew nuts evenly so that the reflector does not move. Monitor the targets through the transit continuously during this entire operation and keep checking the transit for level and alignment with the baseline.

4.2

The probes may be removed at this time or it may be decided to leave them in place in case a future realignment is contemplated. If all work has been done correctly and accurately, there is no reason to think that a return trip will be necessary.

4.3

Check all adjustment hardware tight and all lockbolts and ½" spacers in place and tight. The work is finished.

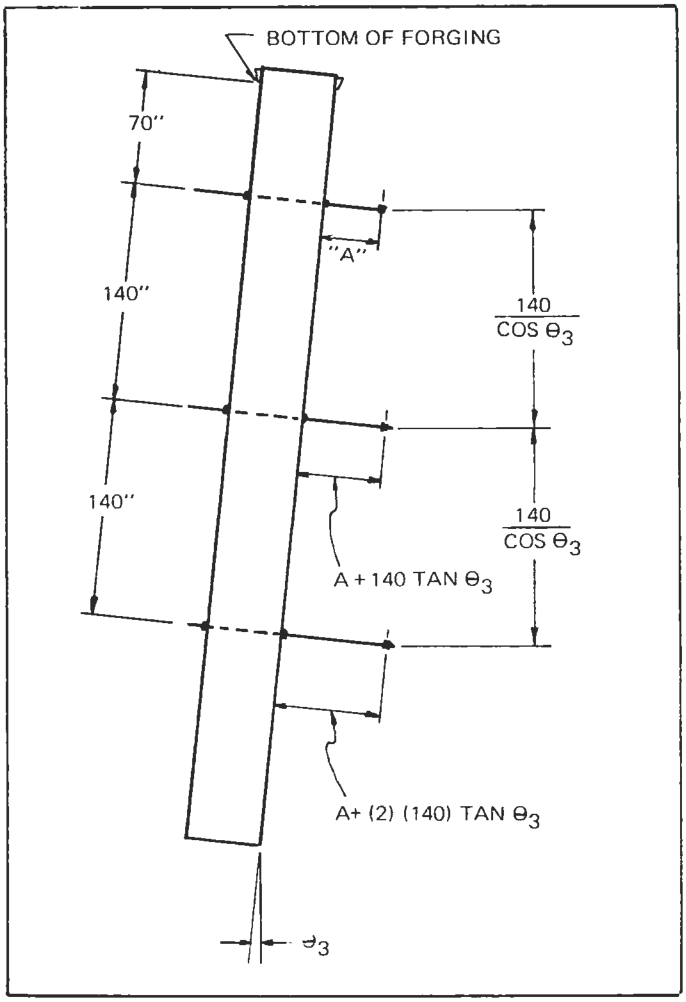


FIGURE 4. Calculating Probe Locations

When the system is energized, the received signal will be less than calculated and there will be a temptation to suspect that the passive is at fault. However, if the work described herein has gone well, treat the system as any single direct path between antennas and perform the usual tests for antenna orientation, polarization, waveguide, damage, and so forth, and get back to the passive only when everything else is proven to be operating properly.

ADDITIONAL NOTES AND COMMENTS

(1) Phase I, as described, is predicated on the antennas being in place and visible from the passive repeater. This does not preclude the possibility that a competent and experienced surveyor might establish the bearings from the passive to the antennas, and calculate the vertical path angles within an accuracy of one minute of arc ..... all without visual reference to the antennas. It depends upon who is available and the accuracy and availability of existing geodetic control points and benchmarks in the vicinity.

(2) When Phase II is begun, it might turn out that the baseline is further out in front of the passive than optimum for the placement and observation of the targets. If this is so, a parallel baseline could easily be established in a location more favorable to the position of the targets.

(3) If the face angle is in excess of 5° downward, the length of the lower probes will be excessive and considerable droop will result. The probe may be supported at the end with a string tied to the upper probe near the panelface. In any event, it is necessary to position the target within ±½" of the proper vertical location. See Figures 2 and 6.

When supporting the probes in this manner, set the probe distance equal to

$$\frac{140}{\cos \theta_3}$$

See Figure 4.

(4) Access to the face of the reflector requires sixty feet of ladder. The face is very smooth and the ladder must be tagged both ways to prevent a serious accident.

(5) An alternate method of setting the targets on the probes would be to install and measure the one upper probe and then do the calculations and set the target on the remaining eleven probes on the ground before installation.

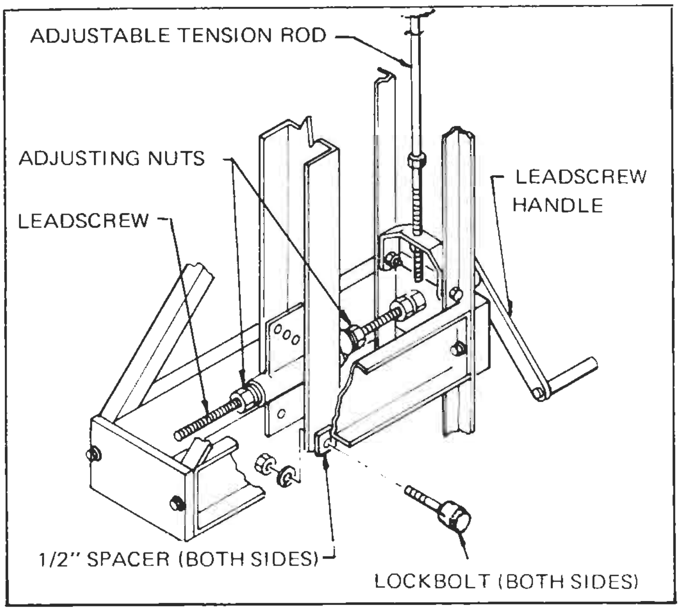
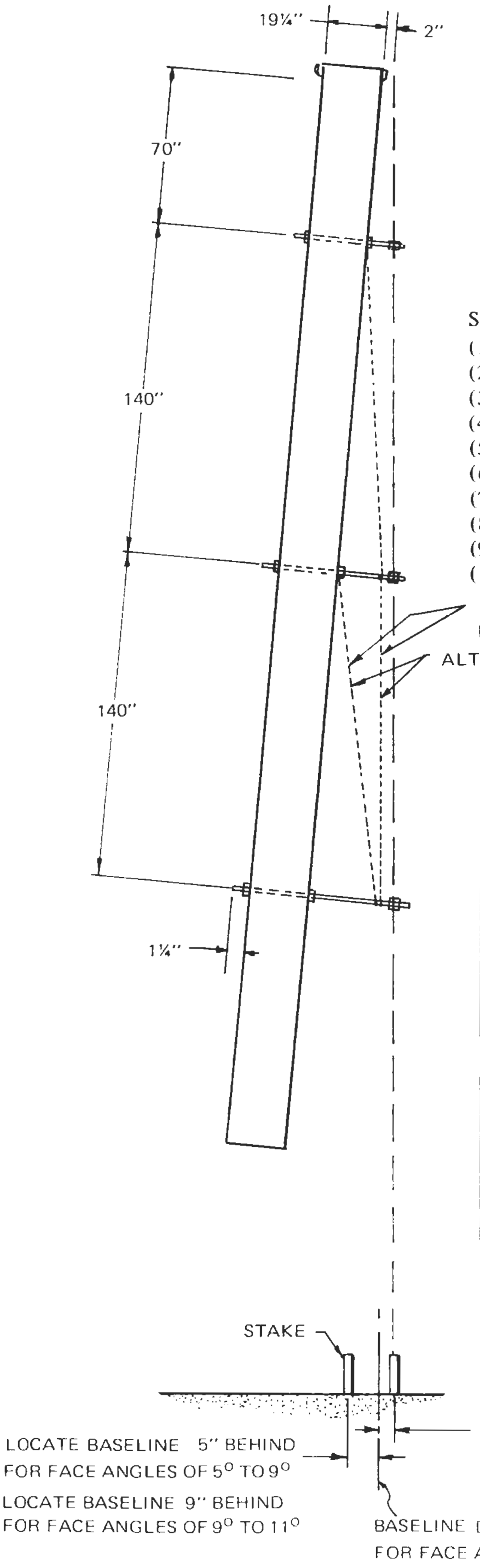
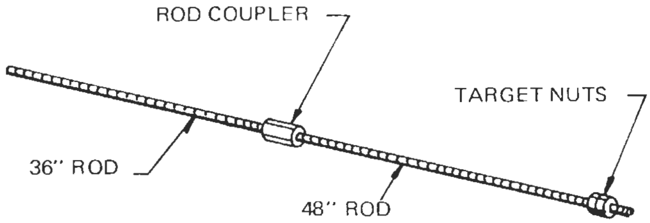


FIGURE 5. Components of Typical Adjustment Mechanism





DETAIL OF BOTTOM PROBE

$\theta_3 = 7^\circ$ TO 11°

SUGGESTED TOOL LIST

(1) Transit with 90° eyepiece.
(2) Seven surveyor's wooden stakes and tacks.
(3) Sixty feet of chalkline cord.
(4) Two 6' folding whiteface rules.
(5) Sixty feet of ladder with tag lines, or bosun's chair and rigging.
(6) Two each open end wrenches, size 1-5/8", 1-1/8" and 9/16".
(7) One pair channel grip pliers
(8) One 12' tape
(9) Small can of oil for the leadscrew nuts.
(10) Hammer.

ITEM	QUANITY REQUIRED		
	FACE ANGLE		
	0°– 3°	3°– 7°	7°– 11°
3/8 ROD, 30" LONG	4	4	4
3/8 ROD, 36" LONG	4	—	4
3/8 ROD, 48" LONG	4	4	4
3/8 ROD, 60" LONG	—	4	4
3/8 ROD COUPLERS	—	—	4
3/8 NUTS	50	50	50
3/8 FLAT WASHERS	25	25	25

INSTALLATION OF RODS			
POSITION	LENGTH REQUIRED		
UPPER ROW	30"	30"	30"
CENTER ROW	36"	48"	60"
BOTTOM ROW	48"	60"	84"*

* MAKE FROM A 48" AND A 36" ROD

FIGURE 6. Method of Supporting Probes

To use a transit to correctly position a double passive repeater, it is required that the transit be located directly under the center of each passive and sights taken parallel to the incident and reflected beams.

STEP I

Locate stakes and tacks directly under the center of each passive. The best method to accomplish this varies depending upon whether or not the center of the passive occurs at a casting cluster, in the center of a panel, or a combination of the center of two panels and along the space between two panels. A passive with an up angle is an additional complication.

Occasionally a plumb bob may be attached to the center of the passive which locates the proper point on the ground. This requires the absence of wind and a down angle on the passive face.

More often it is necessary to use the transit and two setups to locate a "cross" on the ground, the center of which is the desired point.

STEP II

Set the transit up under the center of the first passive to be set. This is usually the passive with the nearest antenna. Determine the distance of the eyepiece below the passive center and set a target the same distance below, and directly under, the center of the second passive. The target can be supported on a board which is wedged under the passive in the proper position or can be hung on a string which is strung between the center and tack below. A sight line between the transit and the target parallels an imaginary line connecting the centers of the two passives. Accuracies will depend on size of passive and frequency along with dependence on optical positioning for the final position.

STEP III

With the transit set up under the center of one passive......

(a) Sight on the target and read the vertical angle θ_1 and record (have the table set on zero degrees).

(b) Rotate the transit and sight in line with, and below the antenna the same distance as the transit is below the center of the passive. Judge this vertical offset by observing the size of the antenna and don't attempt a greater accuracy than $0^{\circ}01'$. Record the horizontal angle 2α and the vertical angle θ_2.

(c) Using Microflect's form, calculate the horizontal correction angle $\Delta\alpha$, and the face angle θ_3.

STEP IV

Bisect the horizontal included angle 2α and add the correction angle $\Delta\alpha$ to rotate the transit toward the path with the least algebraic vertical angle.* Set a stake and tack in a convenient location. The line from the transit to this stake is the correct passive repeater bearing in the horizontal plane.

STEP V

With the transit sighted on this stake, set the table to 90°. Rotating the transit to the 0° or 180° position places the transit exactly parallel to the correct passive face position.

STEP VI

Secure two white face rules to the lower edge of the passive near the ends and index them so that comparable readings are parallel to the face. Adjust the face horizontally until the same readings appear with the transit in the 0° and 180° positions. This passive is now on the correct horizontal bearing.

STEP VII

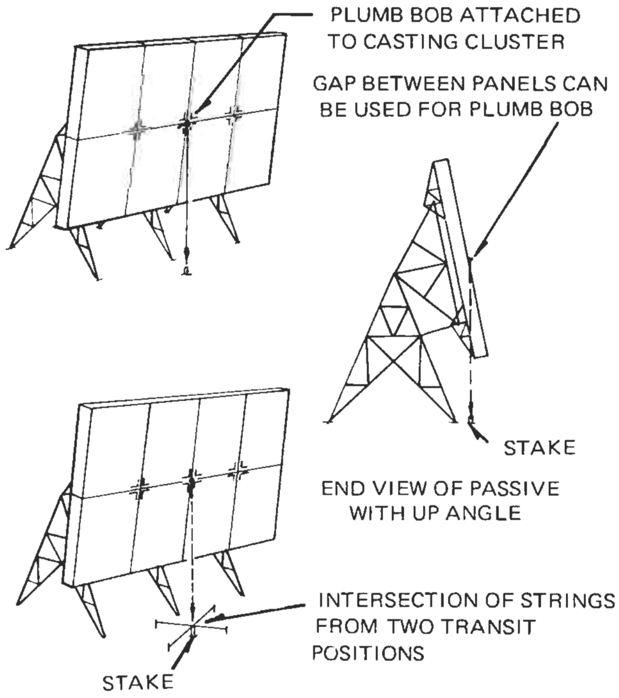
Multiply the vertical dimension of the passive by the tangent of θ_3 (from the calculation sheet) to obtain the offset dimension necessary to properly set the vertical face angle θ_3. Note the individual panels are 96" by 120" with 5/8" spacing between panels. Thus, the vertical dimension of a 30 x 40 passive, for example, would be 361.25 inches which is (3 x 120) + (2 x 5/8).

STEP VIII

Set the transit up to one side of the passive in a position to view the face as a line. Position the rule to make it visible from the transit and adjust the vertical face angle until the proper reading is obtained. On passives larger than 30 x 32 it is a good idea to repeat this step on both ends of the passive.

Repeat steps II through VIII with the second passive. If these steps are performed correctly and accurately, the passives are optimized and should be secured and left alone.

The weak point in the procedure is the ability to sight the more distant antenna. Flashing the path is oftentimes successful depending upon the path length and clearness of the atmosphere. If the long path cannot be located at least set the one passive and then optimize the second with the radio equipment.



STEP I

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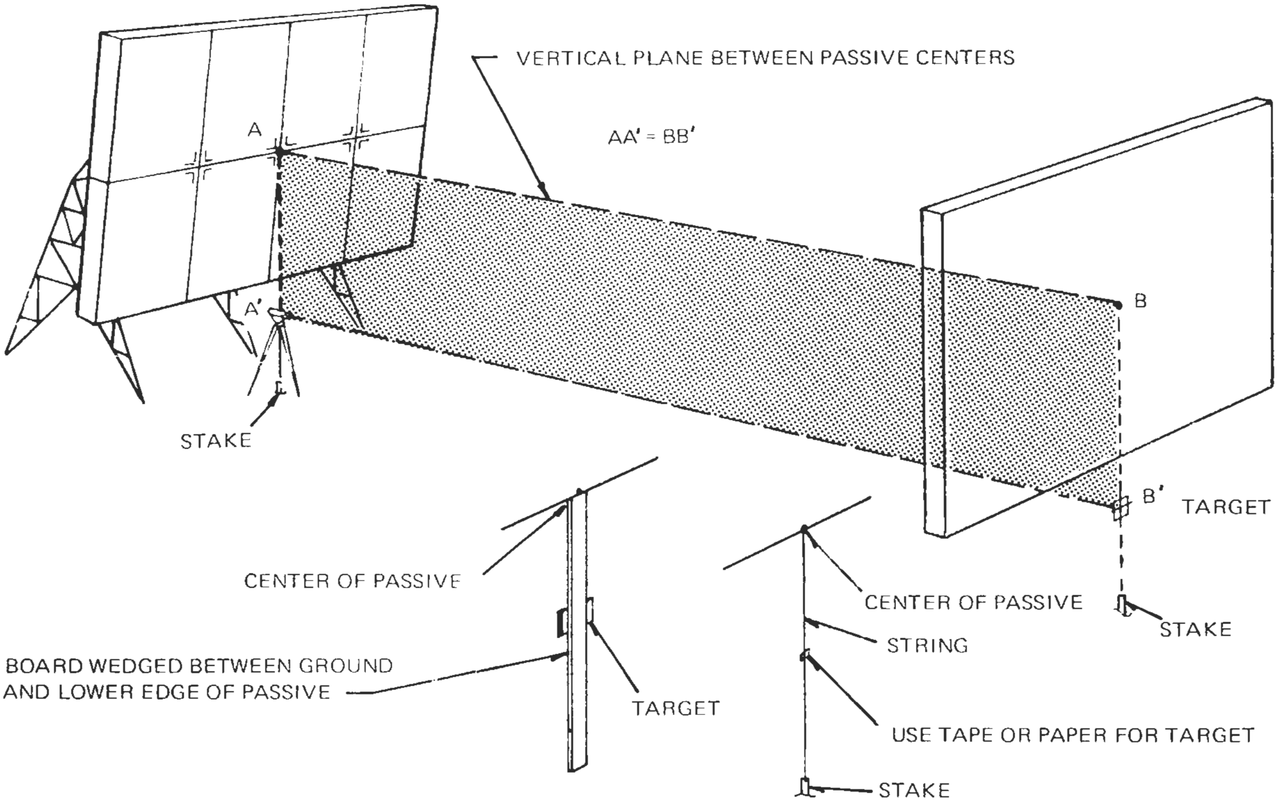
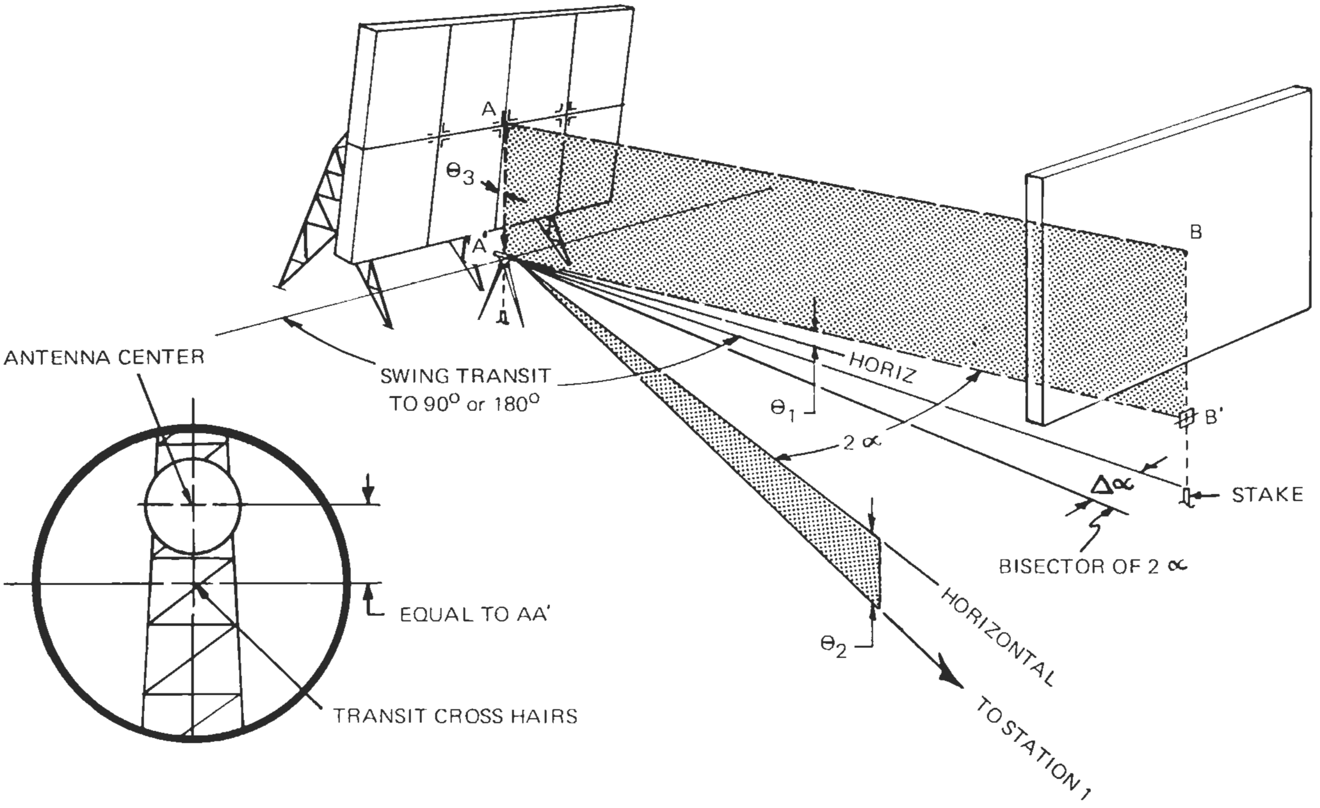
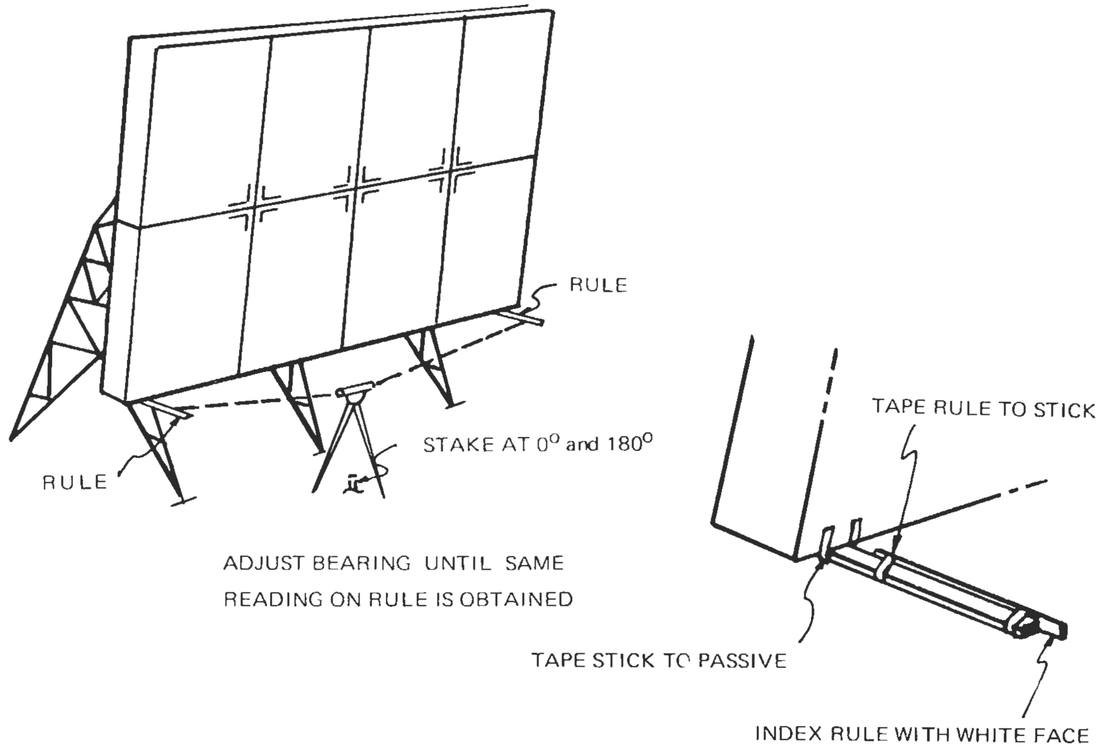
* Toward the path which is more nearly horizontal.



STEP II

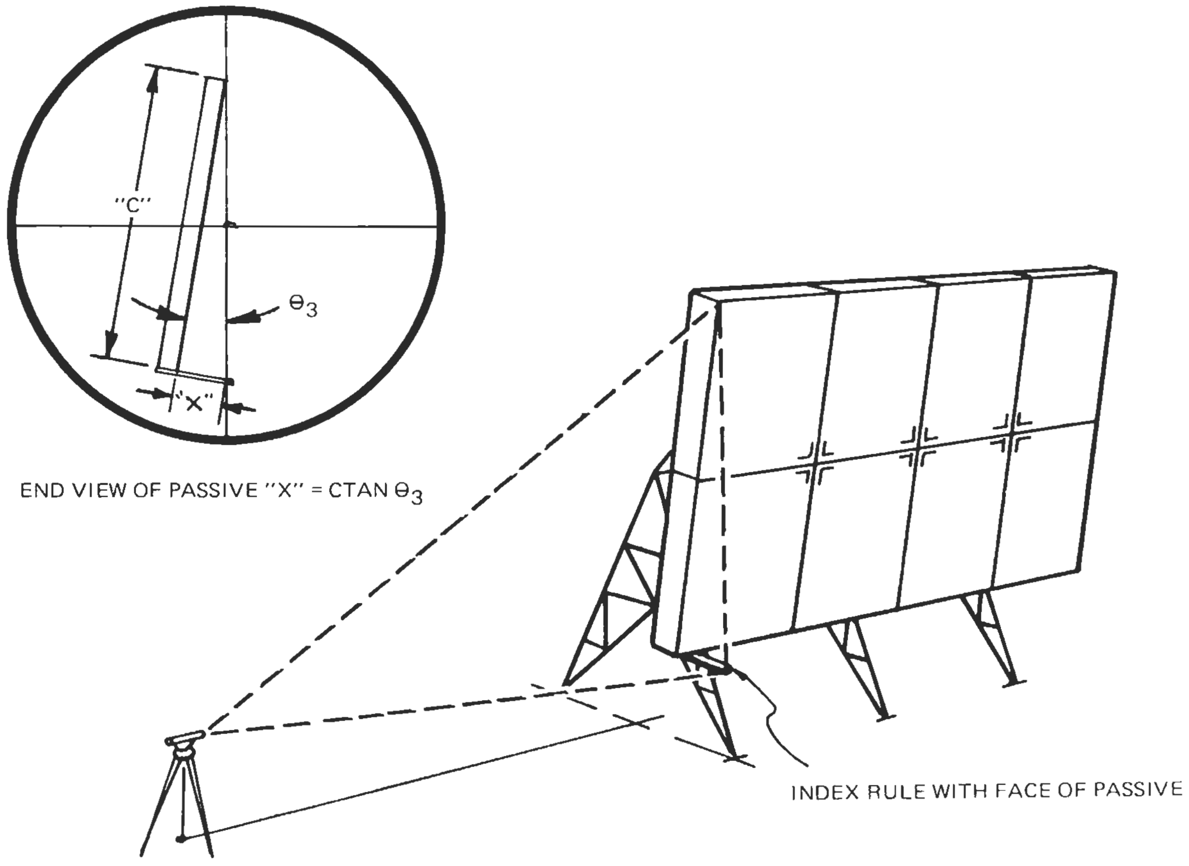


STEP III, IV and V



ADJUST BEARING UNTIL SAME READING ON RULE IS OBTAINED

STEP VI



END VIEW OF PASSIVE "X" = CTAN Θ_3

STEP VII and VIII

ARCTIC PASSIVE REPEATERS

Fifteen models of arctic passive repeaters are available, from 8' x 10' to 40' x 60', all with a nominal fifteen foot ground clearance. These passives have been specifically designed for use in Alaska, Northern Canada, British Columbia, and any area with a similar environment.

Design Loads

Arctic passives are designed in accordance with E.I.A. Specification RS-222-C for the following loading conditions:

(a) 60 PSF wind (122 mph) plus 4 inches of radial ice at 50 lbs/ft^3.

(b) 30 PSF wind (86 mph) plus 12 inches of radial ice at 30 lbs/ft^3.

Rigidity

The reflecting surface of the Arctic passives will remain in position within ± 0.25° under loading (a) or (b) above.

Face Flatness

Under no load the face flatness is within ± 1/16 inch.

Face Deflection

Under 75 mph winds the deflection of the face stiffeners will be less than 1/8" from the no-load position.

Adjustability

Units up to 30 x 48 have maximum adjusting ranges of ±4° about either axis or ± 2° about both axis simultaneously. Sizes 40 x 50 and 40 x 60 have azimuth only adjustment of ± 1°42', elevation only ±2°33', and comined azimuth of ± 0°51' and elevation ±1°16'.

Steel Supporting Structure

All structural steel is galvanized after fabrication in accordance with ASTM A-123 for structural members and A-153 for hardware. A-441 Steel (50,000 psi minimum yield), or an equivalent, is used in the supporting structure in conjunction with A-325 bolts, heavy lockwashers, and nuts.

Reflecting Panels

The reflecting face is 0.063" 6061-T6 aluminum. All panels, for sizes 14 x 16 and up, are totally enclosed.

Painting

The steel supporting structure is shop painted with a flat black paint. Black deicing covers are also included.

Snow Load Struts

Arctic passives, 14 x 16 and up, are supplied with snow load struts to carry the ice load from the panels directly down to the footings.

Design Stresses

Both the steel and the aluminum structures are designed for the loading conditions specified with a factor of safety of 1.65 to the yield point of the material. Steel design is based on the specifications contained in the AISC Manual of Steel Construction, while the aluminum design is based on MIL-Spec 5. Arctic models are designed with the same general configuration as the standard models and have the same pier spacing and anchor bolt arrangement.* The design loads are selected, not in anticipation of actually experiencing these specific loading condition, but rather to provide a criteria for the selection of member sizes that will result in a structure that will adequately resist the severe arctic weather, whatever it may be at any particular site.

On the larger units, the panels are totally enclosed (skinned on the back) to provide additional strength to the panel structure and to limit the buildup of ice and snow by eliminating the open box structure and reducing the number of exposed members that would otherwise accumulate ice and snow.

Snow load struts are incorporated in the design to carry the weight of ice and snow from the reflecting panels directly to the footings. This reduces the load carrying requirements of the main structure and, more importantly, it greatly reduces the structural deflection and thus improves the overall rigidity of the unit. A-441 steel has been selected for the supporting structure because the 50,000 psi yield point of the material provides the individual members of the structure with additional strength to resist bending loads from the snow-pack which may be fifteen or twenty feet deep. This is particularly important for the secondary members, which are usually comparatively light members, and are the first to be damaged in a snow-pack condition. Temperatures in the -70°F range may be experienced for which there are no adequate design guides available in the literature. By using A-441 steel, cold temperature failures should be avoided, although no guarantee is possible.

The steel supporting structure is painted black so that the heat absorbed by the black steel is conducted into the members covered by snow. This heat melts a cylinder in the snow around the members and thus contributes to the elimination of snow-pack damage.

MODEL NUMBER	SIZE (FEET)	WEIGHT (POUNDS)		
		STEEL	PANELS	TOTAL
4060-15A	40 x 60	35,690	9,000	44,690
4050-15A	40 x 50	35,690	7,500	43,190
3048-15A	30 x 48	18,460	5,400	23,860
3040-15A	30 x 40	17,100	4,500	21,600
3032-15A	30 x 32	10,780	3,600	14,380
2430-15A	24 x 30	8,440	2,700	11,140
2032-15A	20 x 32	8,070	2,400	10,470
2024-15A	20 x 24	7,370	1,800	9,170
1624-15A	16 x 24	5,310	1,300	6,610
1620-15A	16 x 20	5,310	1,040	6,350
1416-15A	14 x 16	3,130	920	4,050
1216-15A	12 x 16	2,800	660	3,460
1016-15A	10 x 16	2,800	580	3,380
812-15A	8 x 12	2,060	330	2,390
810-15A	8 x 10	2,060	280	2,340

ALL MODELS HAVE A 15 FOOT GROUND CLEARANCE
(DISTANCE BETWEEN BOTTOM EDGE OF PANELS AND GROUND)

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* Except for additional small piers for snow load struts.

MICROFLECT

Deicing Kits
Installation Instructions

Microflect Company passive repeater deicing kits are available for all Microflect passive repeater models and are designed for field installation. The covers are made from 18 ounce Type ATV plastic coated nylon fabric and are fitted with a PVC pipe frame to space the fabric out from the reflecting surface. When in place the fabric should be taut and all hardware tight. Covers are available in black or dark green. Black covers will be supplied unless green is specified.

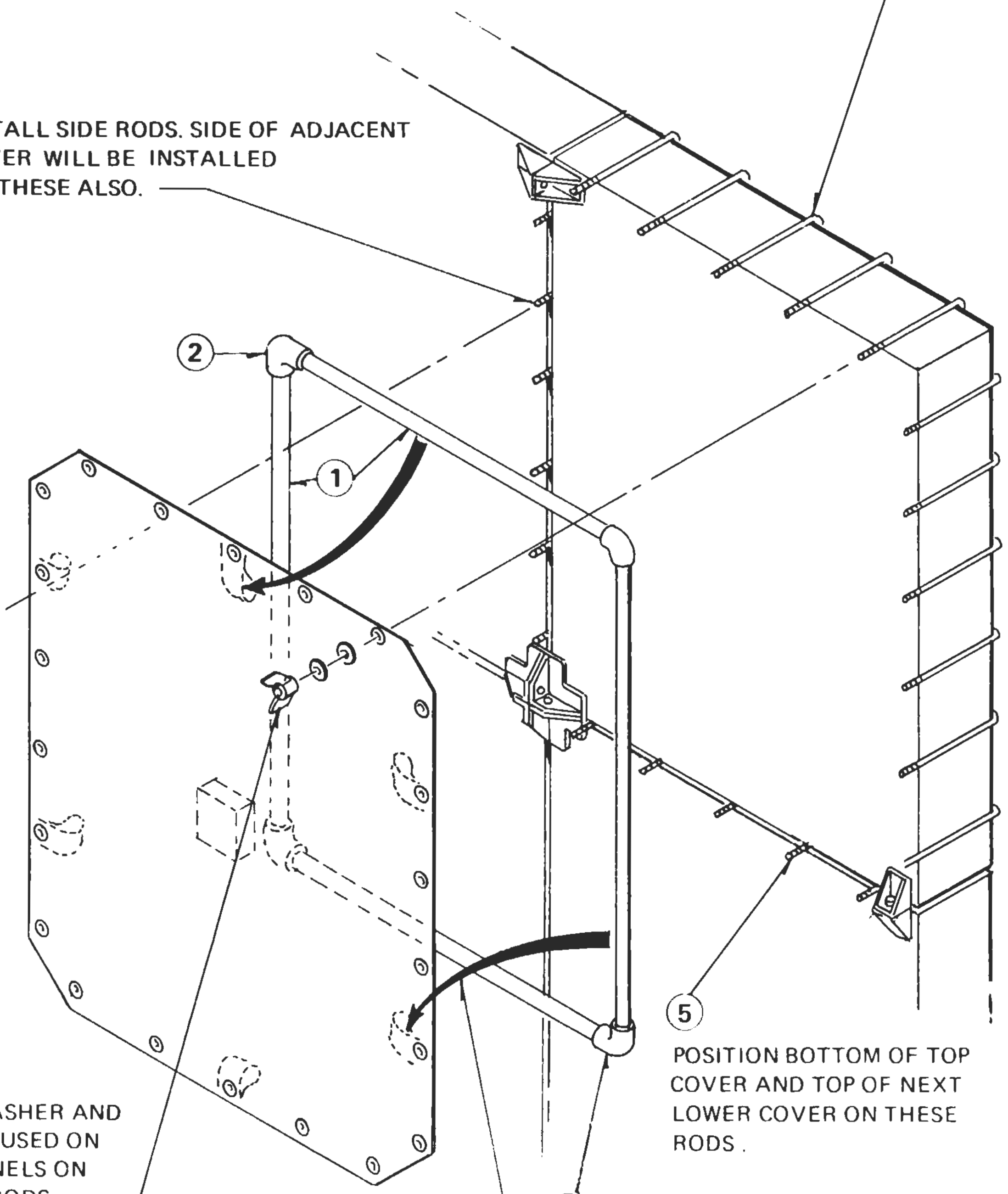
The fabric cover does not prevent the buildup of ice but rather promotes the shedding of ice after a certain accumulation has occurred. The effectiveness of the covers depend upon the type and rapidity of the ice buildup, the action of the wind, if any, and the heat that may be absorbed from the sun. It is not possible to predict the results in advance. However, these covers have been used with success and the chances are good that their use will prevent serious outages due to ice accumulation. If only half the passive repeater is clear of ice the received signal will be down only 6 dB which is acceptable in most circumstances. The installation of these covers can be expected to reduce the passive repeater gain by about ½ dB. at 6 GHz and one dB at 11 GHz.

NOTE: These kits can be ordered factory installed. The factory installed models use inserts in the panels instead of hooks to attach the covers

		ITEMS AND QUANTITY PER DEICING KIT															
PASSIVE SIZE	DEICING KIT NUMBER	DE-ICING COVER 8'x10'	DEICING COVER 8'x12'	DEICING COVER 7'x8'	PLASTIC PIPE 87" LONG	PLASTIC PIPE 112" LONG	PLASTIC PIPE 75" LONG	PLASTIC PIPE 136" LONG	PLASTIC ELBOWS	HOOKS 3/8" x 15¾" LONG	HOOKS 3/8" x 21¾" LONG	RODS 3/8" x 16½" LONG	RODS 3/8" x 22½" LONG	WING NUTS 3/8"	NUTS 3/8"	FLAT WASHERS 3/8"	LOCK WASHERS 3/8"
40 x 60	DK4060	30			60	60			120		122		269	391	269	660	660
40 x 50	DK4050	25			50	50			100		110		220	330	220	550	550
30 x 48	DK3048	18			36	36			72		96		150	246	150	396	396
30 x 40	DK3040	15			30	30			60		86		122	208	122	330	330
30 x 32	DK3032	12			24	24			48		76		94	170	94	264	264
24 x 30	DK2430	9			18	18			36		66		66	132	66	198	198
20 x 32	DK2032	8			16	16			32		64		56	120	56	176	176
20 x 24	DK2024	6			12	12			24		54		39	93	39	132	132
16 x 24	DK1624		4		8			8	16	48		24		72	24	96	96
16 x 20	DK1620	4			8	8			16	44		22		66	22	88	88
14 x 16	DK1416			4	8		8		16	36		18		54	18	72	72
12 x 16	DK1216		2		4			4	8	34		7		41	7	48	48
10 x 16	DK1016	2			4	4			8	32		6		38	6	44	44
8 x 12	DK812		1		2			2	4	24				24		24	24
8 x 10	DK810	1			2	2			4	22				22		22	22

③ TOP HOOKS OF TOP PANEL ARE INSTALLED FIRST. DRILL A ½" CLEARANCE HOLE FOR HOOK END IF PANEL IS COVERED WITH ALUMINUM SKIN ON THE BACK.

④ INSTALL SIDE RODS. SIDE OF ADJACENT COVER WILL BE INSTALLED ON THESE ALSO.

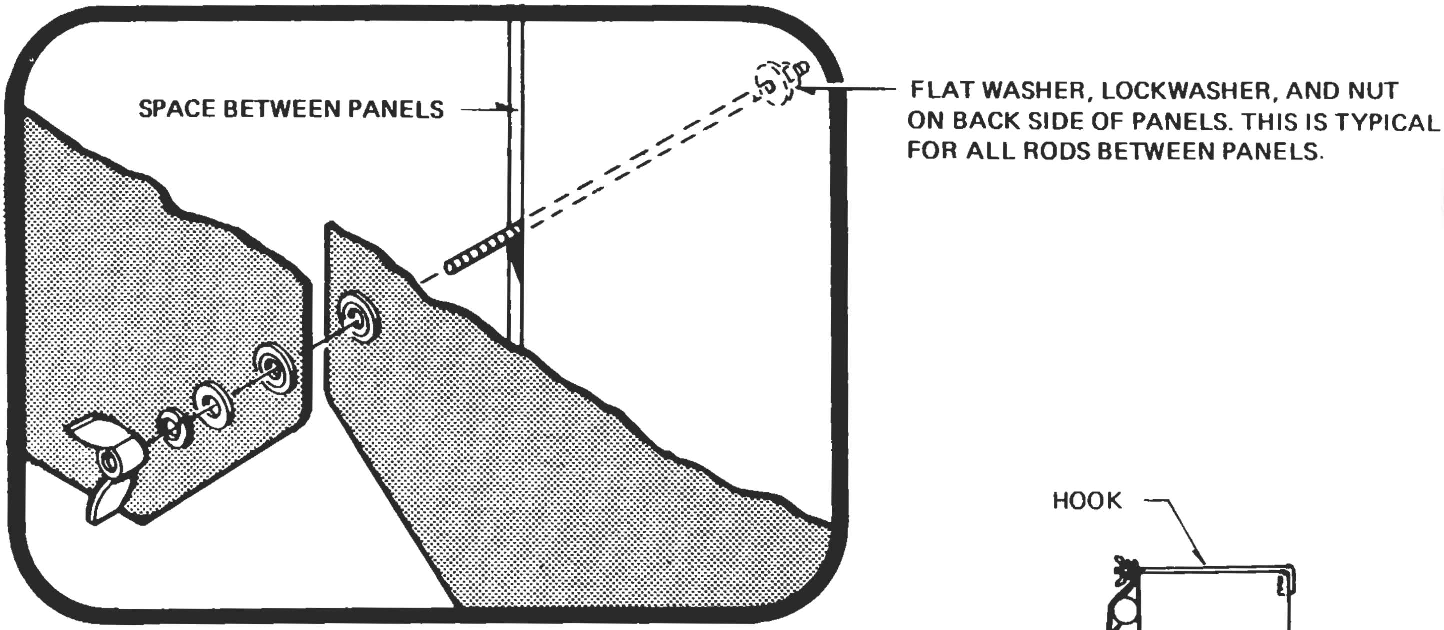


WING NUT, LOCK WASHER AND FLAT WASHER ARE USED ON FRONT SIDE OF PANELS ON BOTH HOOKS AND RODS

⑤ POSITION BOTTOM OF TOP COVER AND TOP OF NEXT LOWER COVER ON THESE RODS.

② INSTALL ELBOWS. TAP ON WITH A HAMMER, NO GLUE IS NECESSARY

① INSTALL PLASTIC PIPE THRU LOOPS ON BACK OF COVER



DETAIL OF COVER OVERLAP
THIS OCCURS BETWEEN ALL PANELS

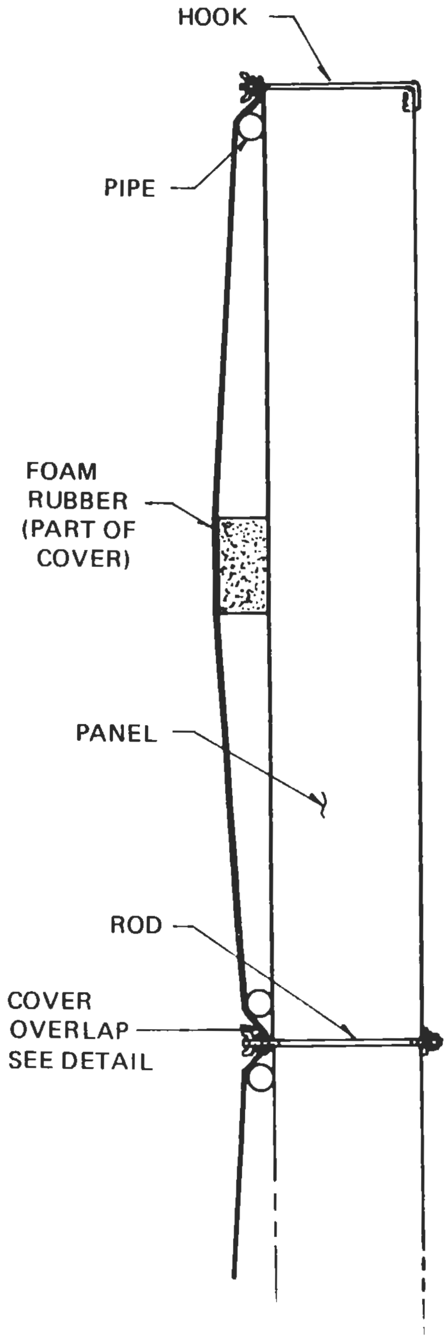
NOTES:

RODS AND HOOKS ARE SHOWN IN POSITION ON THIS DRAWING. THEY MUST, HOWEVER, BE POSITIONED INDIVIDUALLY BY A WORKMAN DURING INSTALLATION OF THE COVERS.

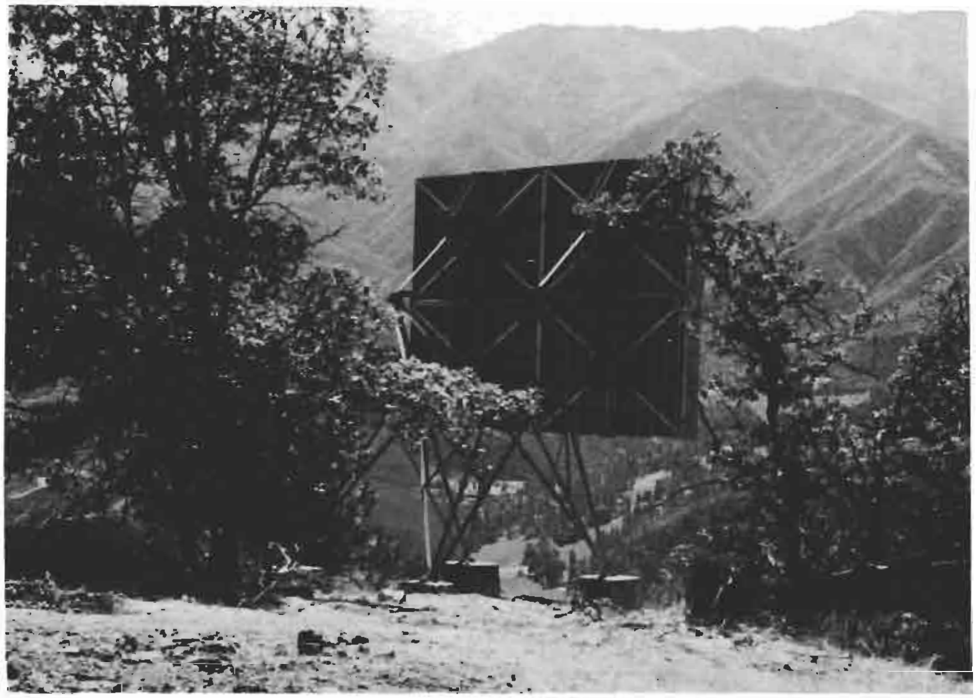
RODS ARE USED BETWEEN ALL PANELS AND HOOKS ARE USED ON THE SIDE, TOP, AND BOTTOM EDGES.

⑥ TIGHTEN ALL WING NUTS UNTIL THE FABRIC BOTTOMS OUT AGAINST THE PANELS.

RODS ARE ALUMINUM AND HARDWARE IS STAINLESS STEEL.



CROSS SECTION
OF FINISHED
INSTALLATION



Ecological damage to our natural environment is becoming a major concern in the communications industry. The passive repeater, which requires no access roads or power lines and minimum maintenance is often the solution to these problems. The passive repeater provides these advantages in terms of ecology:

No noise or harmful radiation.

Land requirements are small and the site does not need to be leveled.

The units do not require aircraft obstruction lighting.

The aluminum face reflects surrounding terrain and provides a natural camouflaging effect. They can readily be painted for special camouflage effects.

Installation access can be accomplished with helicopters.

Passive repeaters allow wider selection of sites during initial planning of microwave paths.

Razing of land for long access roads and power line right--of--ways is not required.

Forest fire hazards are reduced since personnel access is reduced and no power is required.

Inert, non--polluting, non--corrosive materials are used throughout.

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13. "Microwave Antenna Measurements", Scientific - Atlanta, Inc., Atlanta, Ga., 2nd Edition, published 1970

14. "The Physics of Microwave Propogation", Donald C. Livingston 1970 by Prentice Hall Inc., New Jersey

15. Electronics Industry Association, 2001 Eye Street N.W. Washington, D.C. 20006

Notes

CUSTOMER LIST

AT & T Long Lines
Bell of Pennsylvania
Central Telephone of Nevada
Illinois Bell
Michigan Bell
Mountain Bell - Arizona
Mountain Bell - Colorado
Mountain Bell - Idaho
Mountain Bell - Montana
Mountain Bell - New Mexico
Mountain Bell - Utah
Mountain Bell - Wyoming
Nevada Bell
Northwestern Bell
Ohio Telephone
Pacific Northwest Bell
Pacific Telephone
So. Central Bell
Southern Bell
Western Electric

General Telephone of California
General Telephone of Florida
General Telephone of the NW
General Telephone of the SE
General Telephone of the SW
General Telephone of Wisconsin
GTE International
GTE Lenkurt
GTE Sylvania

Blue Mountain Telephone Co.
Continental Telephone of CA
Continental Telephone of Texas
Continental Trading Corp.
C & P Telephone
Hawaii Telephone
Idaho Telephone
Ilwaco Telephone
Lincoln County Telephone Co.
New York Telephone Co.
Peninsula Telephone
Siskiyou Telephone Co.
United Telephone of the NW
Western States Telephone

The Alaska Railroad
Burlington Northern Railroad
Canadian National Railway
Chicago & NW Railroad
Denver & Rio Grande Railroad
Pacific Great Eastern
Seven Islands Railroad
Southern Pacific Railroad
Union Pacific Railroad
Western Pacific Railroad

Atlantic Richfield
Bonneville Power Administration
Cascade Utilities
Chelan County PUD No. 1
Chugach Electric
Citizens Utilities of CA
Duquesne Light
Gulf Oil Co.
Montana Power Co.
Mountain Fuel Supply
Nevada Power Co.
New England Power
Northwest Natural Gas
Ohio Edison
Pacific Gas & Electric
Pacific Gas Transmission
Pacific Power & Light
Portland General Electric
Puget Sound Power & Light
Shell Oil Co.
Sierra Pacific Power
So. California Edison
Standard Oil Co.
Tennessee Valley Authority
Trans. Gas Pipe Line
Tucson Gas & Electric
Utah Power & Light
Washington Gas & Light

Asteroid Corp.
Andrew Corp.
Collins Radio
Farinon Electric
General Electric
Granger Associates
ITT Arctic Services
ITT Commercial Services
ITT Defense Communications
ITT Export Corp.
ITT Telecommunications
Melpar
Microwave Associates
Motorola C & E
RCA Global
RCA Alaska Communications
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American Cable Television
American TV Relay
Columbia Cable TV
Microwave Transmission Corp.
Midwestern Relay
Telepromter Co's
UA–Columbia Cablevision, Inc.
United Cable TV, Inc.

Abroyd Construction
Alberta Telephone (Canada)
Andrew Antenna (Canada)
B.C. Hydro (Canada)
B.C. Telephone (Canada)
Hydro--Quebec (Canada)
Leblanc & Royle (Canada)
Marconi (Canada)

AMOCO Trinidad Oil
Andrew Antennas (Australia)
Andrew Antenna (England)
Australian Post Office (Australia)
Bali International Agencies (India)
Bell Telephone Mfg. of Belguim
Brasil Telephone
Cable & Wireless (England)
Cable & Wireless (Hong Kong)
Collins Radio (Canada)
Collins Radio (England)
Communications Authority (Puerto Rico)
Companhia Tele. de M.G. (Brazil)
Dept. of Posts & Telecomm. (Fiji Island)
Dir. of Posts & Telecomm. (Iceland)
Cominican de Telephones (D.R.)
GEC--Coventry (England)
GEC--(Telecommunications) (Nigeria)
GEC--Venezuela
GTE International (Chile)
GTE International (Hong Kong)
GTE--Madrid (Spain)
GTE--Milano (Italy)
GTE International (Nigeria)
GTE International, Caracas (Venezuela)
GTE Lenkurt (Canada)
GTE Telecomunicaciones (Venezuela)
GTE Telecommunications - (Costa Rica)
Heerema Engineering Service (Holland)
Hellenic Telecommunications (Greece)
Imperial Board of Telecomm. (Ethiopia)
Government of India
Indian Posts & Telegraphs Dept. (India)
Iranian American Oil (Iran)
Government of Israel
ITT Philippines
Jamaica Telephone Co.
Marconi--South Africa
Mitsui & Co. (Japan)
Mobile Oil--Venezuela
Motorola--Israel
Motorola–South Africa
National Iranian Oil (Iran)
(NEC) Nippon Elec. Co. (Japan)
New Zealand Post Office (New Zealand)
Northern Electric (Puerto Rico)
Oceanic Contractors (The Netherlands)
Page Communications Engineers (Australia)
Paterson Simons & Co. (Malaysia)
Philips do Brasil S.A. (Brazil)
N.V. Philips (Holland)
Puerto Rico Telephone Co. (Puerto Rico)
San Juan Electronics (Puerto Rico)
G. Simons Radio (Thailand)
Sumitomo Shoji (L.A. – Japan)
Telettra (Italy)
Trinidad–Tobago Telephone Co.
C.Tennant & Sons
Virgin Islands Telephone Co. (V.I.)

Microflect