TK
7876
C35

Communications Canada

ATLANTIC REGION

Industry Canada
LIBRARY
SEP 11 1998
BIBLIOTHEQUE
Industrie Canada

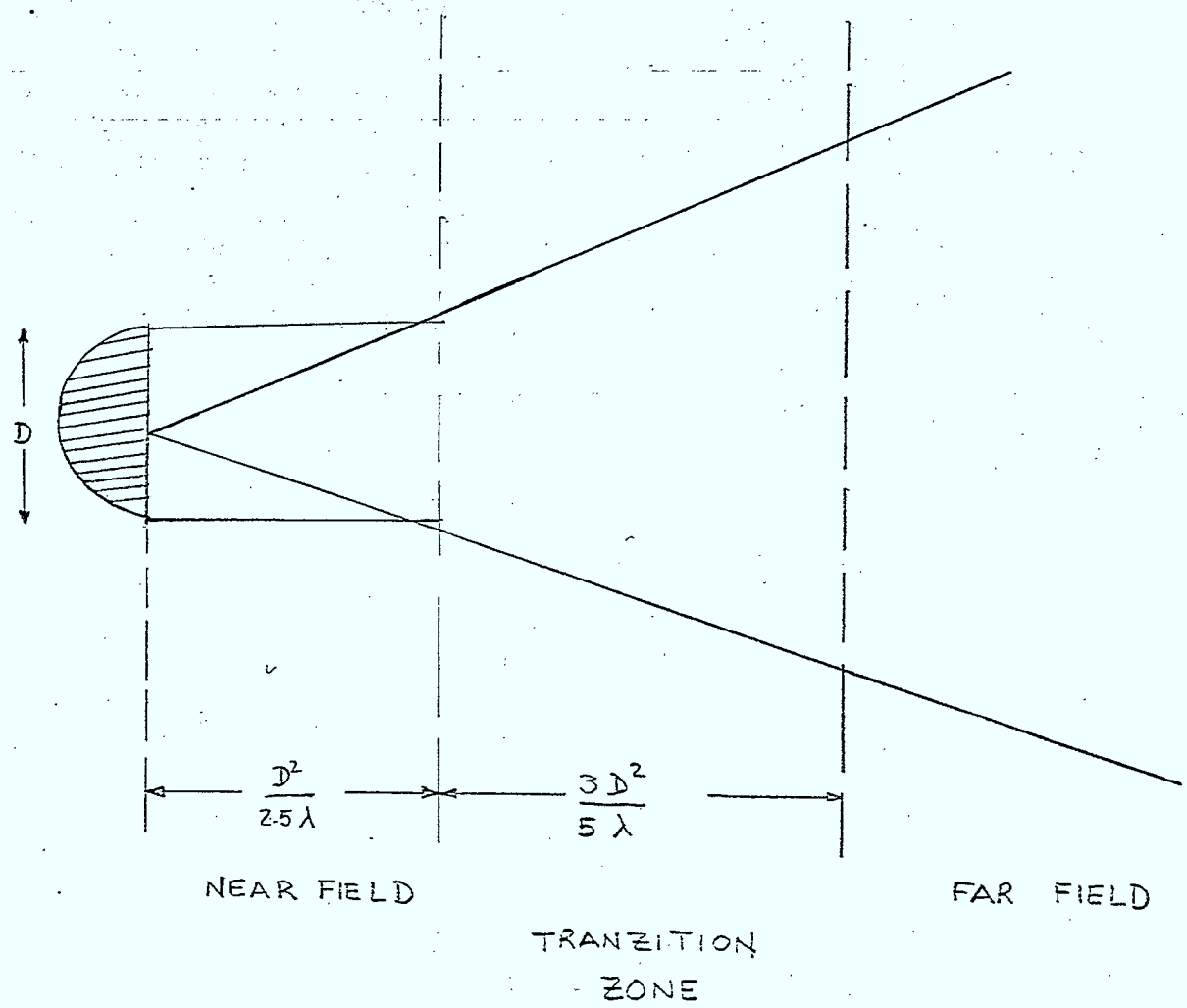
Microwave

COMMUNICATIONS CANADA
SEP 27 1977
LIBRARY - BIBLIOTHEQUE

SYSTEM ANALYSIS

DB 6209287
DL 6209311

TK
7876
C35


D
$\frac{D^2}{2.5\lambda}$
$\frac{3D^2}{5\lambda}$
NEAR FIELD
TRANZITION ZONE
FAR FIELD

NEAR FIELD

$$F.S.L. = 20 \text{ LOG } \left(\frac{4\pi D}{\lambda} \right) , \text{ DB}$$

WHERE D = DISTANCE

λ = WAVELENGTH

$$\text{BLOCKAGE LOSS (DB)} = 10 \text{ LOG } \left(\frac{1}{1-R} \right)$$

WHERE R = $\frac{\text{CROSS-SECTIONAL AREA OF BLOCKING OBJECT}}{\text{CROSS-SECTIONAL AREA OF ANTENNA.}}$

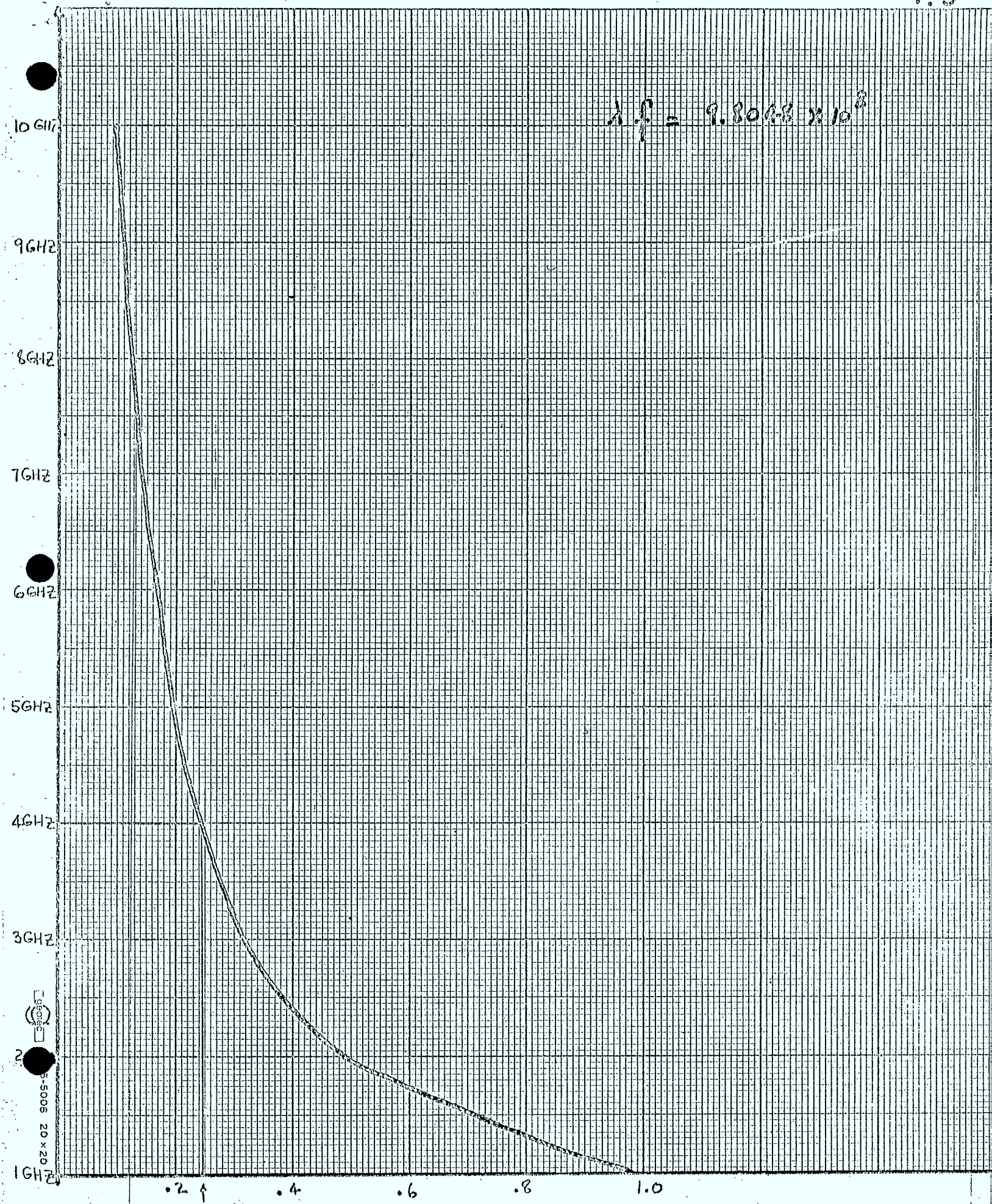
FAR FIELD

$$F.S.L. = 36.6 + 20 \text{ LOG } F + 20 \text{ LOG } D , \text{ DB}$$

WHERE D = DISTANCE IN MILES

F = FREQUENCY IN MEGACYCLES

THE BLOCKAGE LOSS IS MINIMAL UNLESS VERY LARGE OBJECTS PROTRUDE IN THE CONE EXTENDED FROM THE ANTENNA FEEDER DEFINING THE MAIN LOBE (3DB BEAM WIDTH ANGLE).

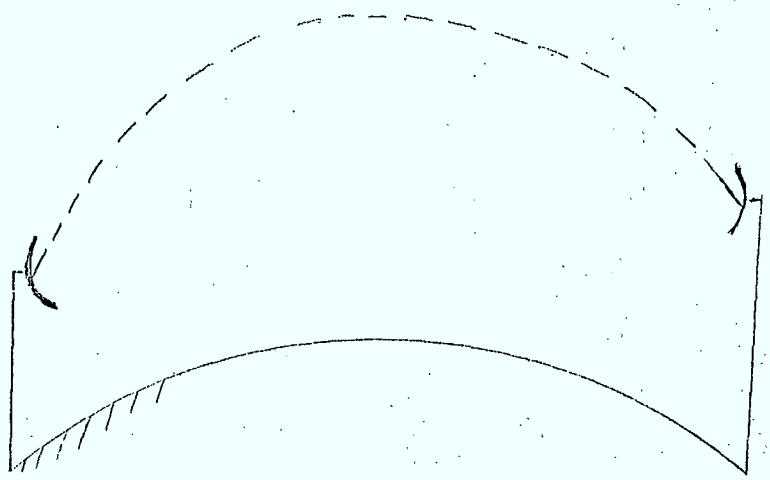

FREQUENCY IN HZ
$\lambda f = 9.8048 \times 10^8$
10 GHZ
9GHZ
8GHZ
7GHZ
6GHZ
5GHZ
4GHZ
3GHZ
2
1GHZ
.2
.4
.6
.8
1.0

IT IS A WELL KNOWN FACT THAT THE ACTUAL PATH TRACED BY A MICROWAVE BEAM IN THE ATMOSPHERE IS NOT A STRAIGHT LINE. THIS BENDING IS CAUSED BY THE CHANGE IN THE ATMOSPHERE WITH HEIGHT, TEMPERATURE, HUMIDITY AND CHANGE IN THE BAROMETIC PRESSURE.

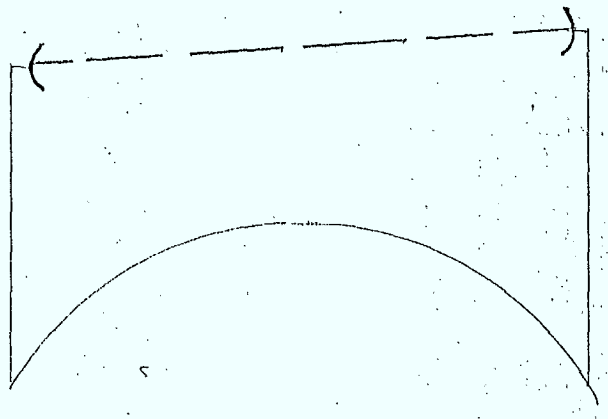
THESE CHANGES AFFECT A VARIABLE WHICH MEASURES THE PROPAGATION LOOSENESS IN THE ATMOSPHERE AND IS CALLED THE REFRACTIVE INDEX.

THE LOWER THE REFRACTIVE INDEX THE FASTER THE WAVE WILL TRAVEL.

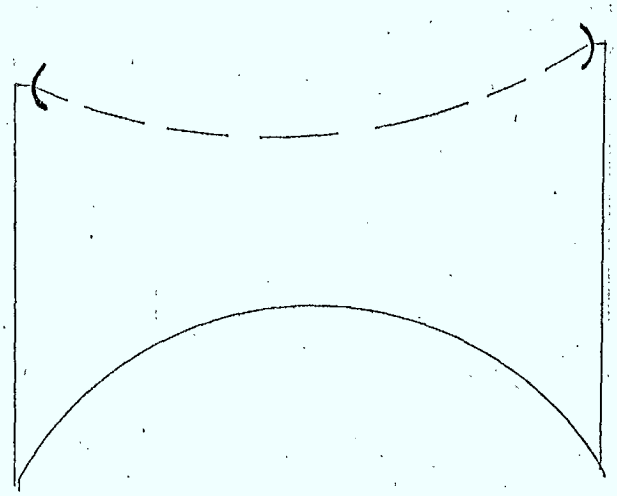
UNDER NORMAL CONDITIONS THE REFRACTIVE INDEX DECREASES WITH HEIGHT. THIS COULD MEAN THAT THE TOP PARTS OF THE WAVE TRANSMITTED BY THE ANTENNA WILL TRAVEL FASTER THAN THE BOTTOM PARTS. THIS WILL CURVE THE WAVE PATH TOWARD THE REGION OF INCREASING REFRACTIVE INDEX.



A) REFRACTIVE INDEX DECREASES WITH HEIGHT



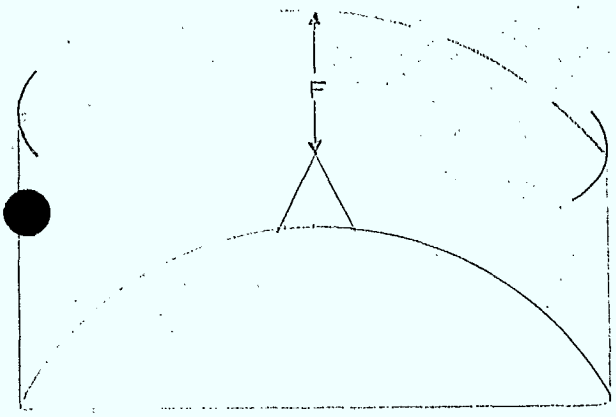
B) REFRACTIVE INDEX IS CONSTANT



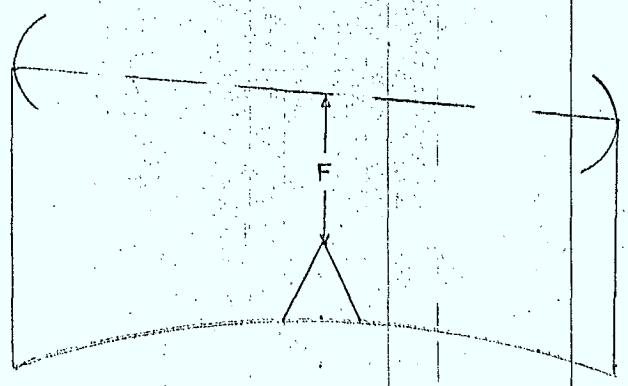
C) REFRACTIVE INDEX INCREASES WITH HEIGHT

TO MAKE PATH PROFILES IN THIS MANNER A TEDIOUS AFFAIR SINCE TWO CURVED SURFACES HAVE TO BE DRAWN.

TO SIMPLIFY MATTERS IT WAS DECIDED TO DRAW THE BEAM AS A STRAIGHT LINE AND CHANGE THE TRUE CURVATURE OF THE EARTH TO ACCOMMODATE THE ADDITIONAL CURVATURE OF THE MICROWAVE BEAM.



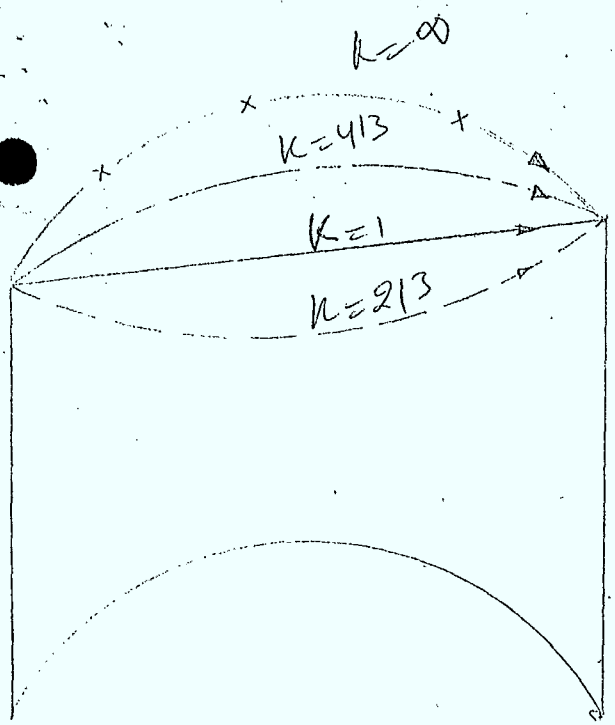
ACTUAL EARTH RADIUS R_o



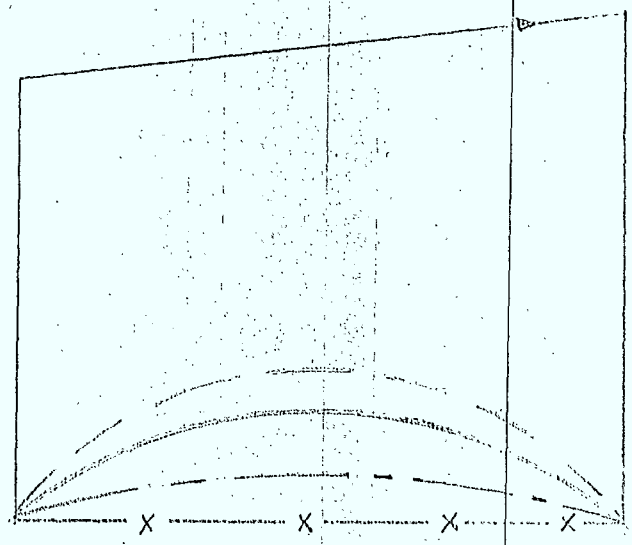
EFFECTIVE EARTH RADIUS R

$$K = \frac{R}{R_o}$$

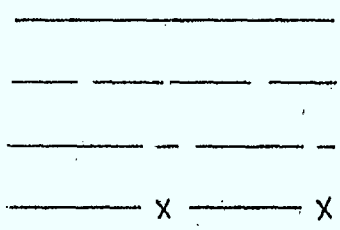
NOTE THAT THE CLEARANCE F HAS NOT CHANGED IN BOTH PROFILES AND ALL THE OBSTRUCTION FEATURES ARE REPRESENTED IN BOTH PROFILES ALSO.



ACTUAL RAY PATHS ON A MICROWAVE PATH.



RADIO PATH PLOTTED AS A STRAIGHT LINE BY CHANGING THE EARTH RADIUS.



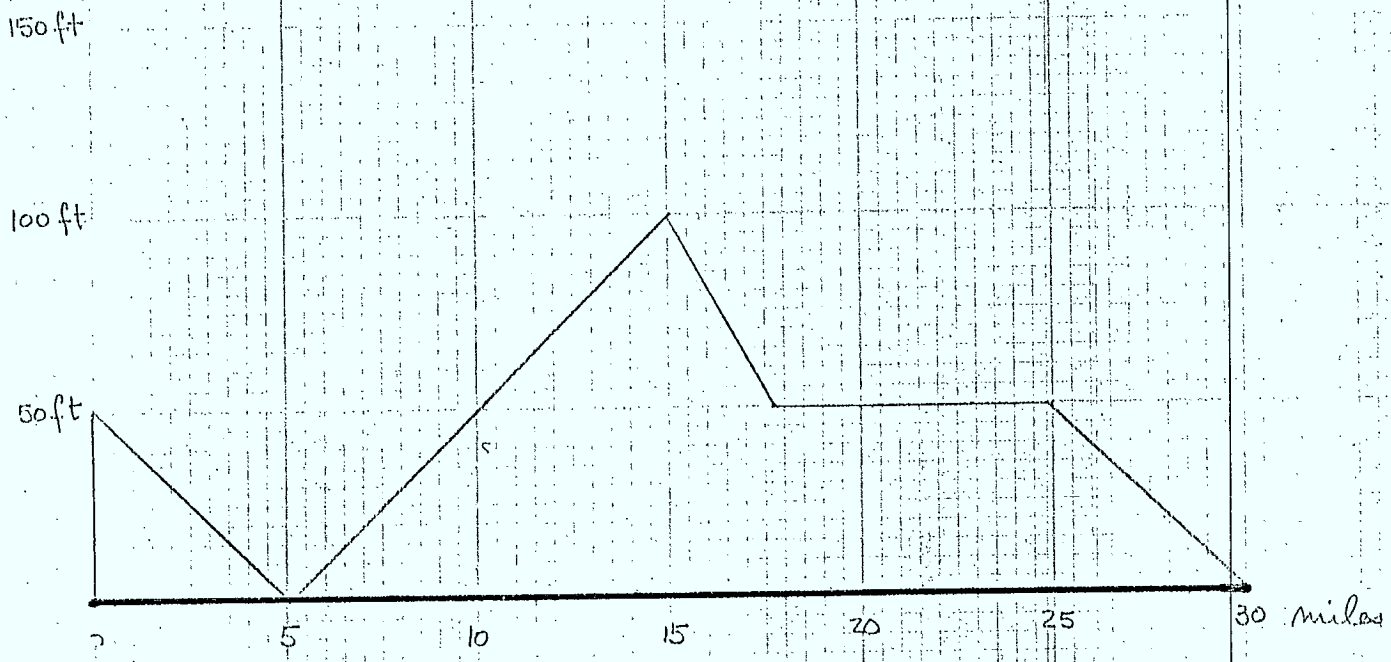
K = 1

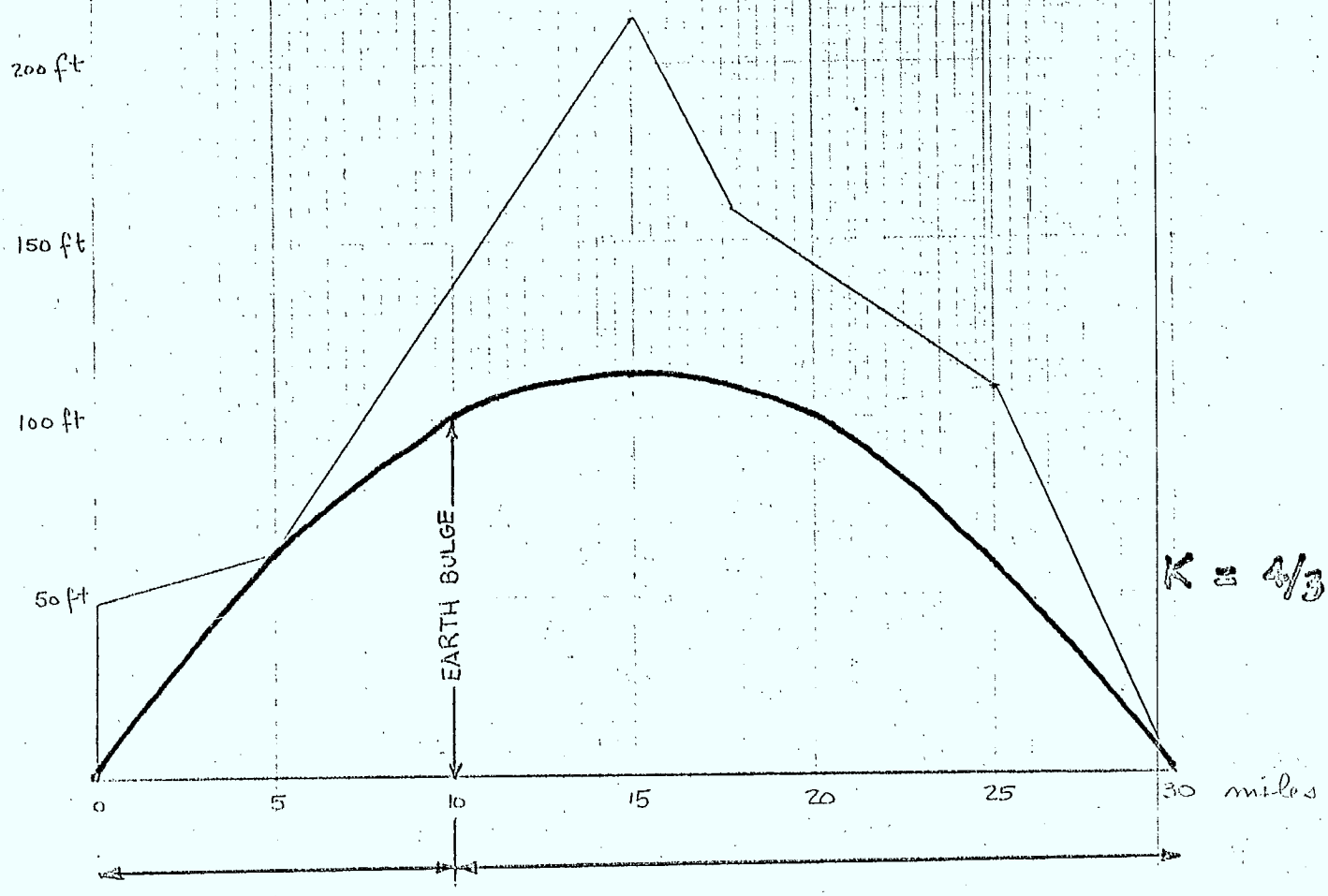
K = 2/3

K = 4/3

K = INFINITY

THE FACTOR K VARIES ALL THE TIME AND FROM ONE LOCATION TO ANOTHER. THE RANGE OF K HAS BEEN KNOWN TO VARY FROM INFINITY TO 1/3.


150 ft
100 ft
50 ft
0
5
10
15
20
25
30 miles


200 ft
150 ft
100 ft
50 ft
EARTH BULGE
0
5
10
15
20
25
30 miles

K = 4/3

$$\text{EARTH BULGE} = \frac{d_1 \, d_2}{1.5 \, K}$$

FOR EXAMPLE AT THE 10 MILES MARK FOR K = 4/3

d_1 = 10 MILES

d_2 = 20 MILES

$$\text{THEN EARTH BULGE} = \frac{10 \times 20}{1.5 \times 4/3} = 100 \text{ FT.}$$

FIND THE BULGE AT 15, 25 MILES FOR K = 4/3

FIND THE BULGE AT 15, 25 MILES FOR K = 2/3

FIND THE BULGE AT 15, 25 MILES FOR K = INFINITY

AS STATED PREVIOUSLY BENDING THE MICROWAVE BEAM DEPENDS ON THE VALUE OF THE REFRACTIVE INDEX. FROM THIS IT FOLLOWS THAT K SHOULD BE RELATED TO THE REFRACTIVE INDEX.

THE NATIONAL BUREAU OF STANDARDS HAS ISSUED A WORLD ATLAS OF ATMOSPHERIC RADIO REFRACTIVITY COMPILED FROM MEASUREMENTS DONE ALL OVER THE WORLD FOR MANY YEARS. THIS ATLAS IS NOT AS DETAILED AS IT SHOULD BE. HOWEVER, DETAILS ARE AVAILABLE FOR THE U.S.A.

P. 11

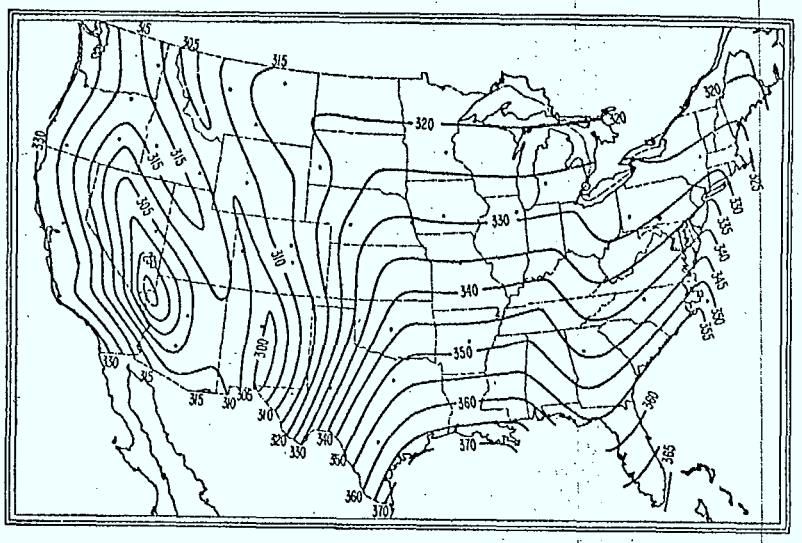


FIGURE 9.3. *Mean* N_0, *May 0200.*

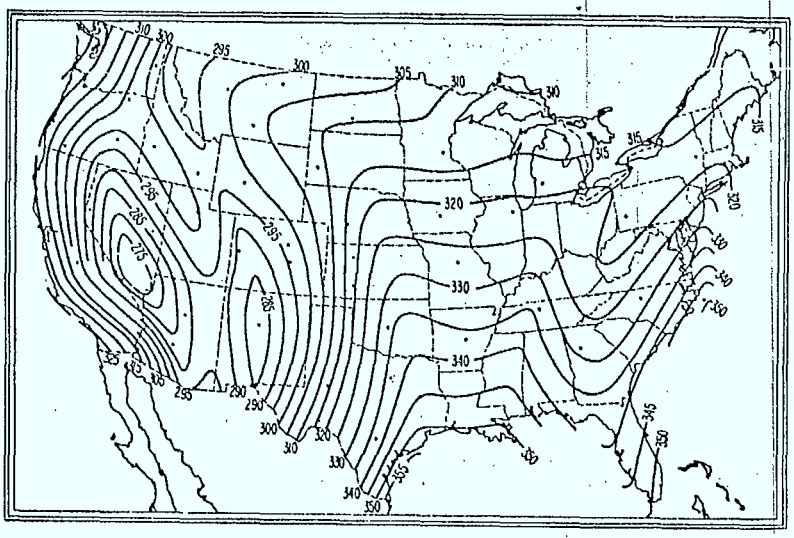


FIGURE 9.4. *Mean* N_0, *May 1400.*

P. 10

ONS

e Index

ime are given

nal variations
se are plotted
nges of means
red with the
toosh Island
ith those ob-
e over North
seasonal and
ns (Colorado
oosh Island).

bending pre-
ations above.

a measure of
s been noted
the standard
the country,
d deviations
ap[illegible]on, the
eping across
ndard devia-

le Error

ike bending,
of the form

and ℓ have
ie Standard

ion method

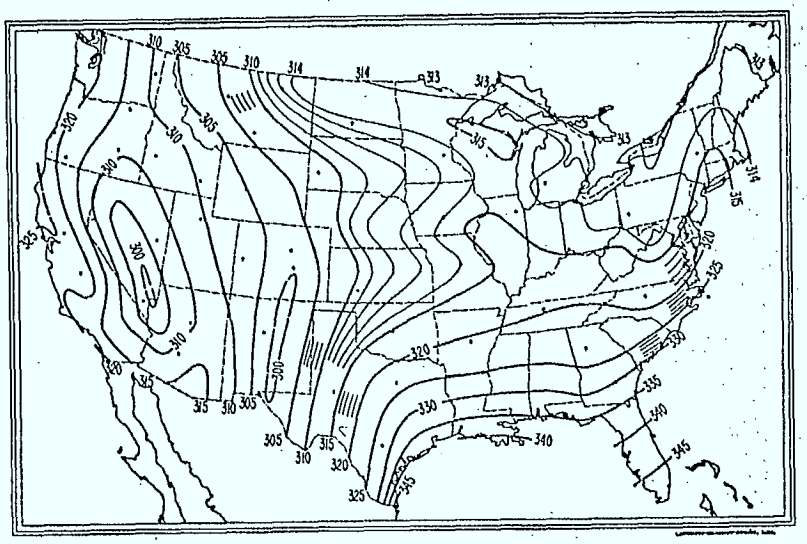


FIGURE 9.1. *Mean* N_0, *February 0200.*

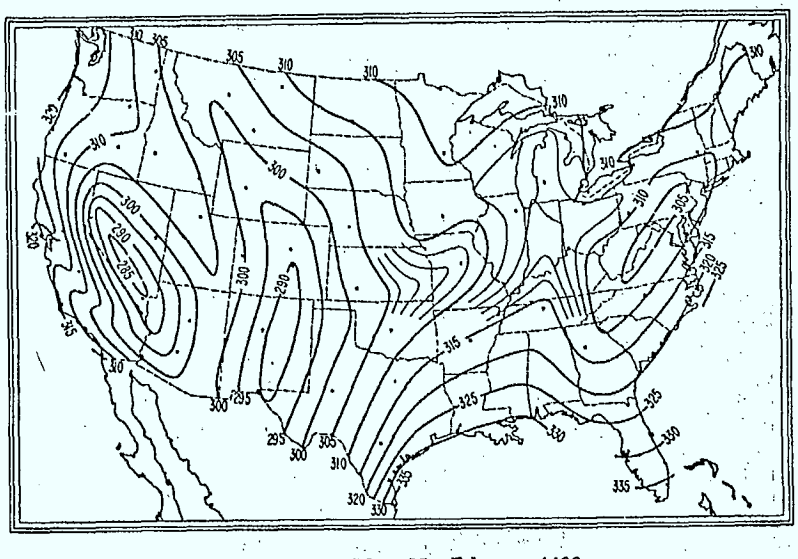


FIGURE 9.2. *Mean* N_0, *February 1400.*

P. 12

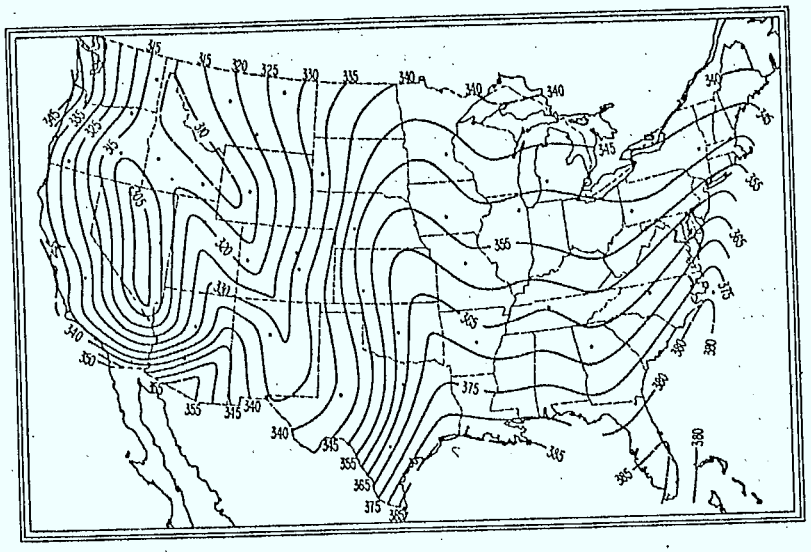


FIGURE 9.5. *Mean* N_0, *August 0200.*

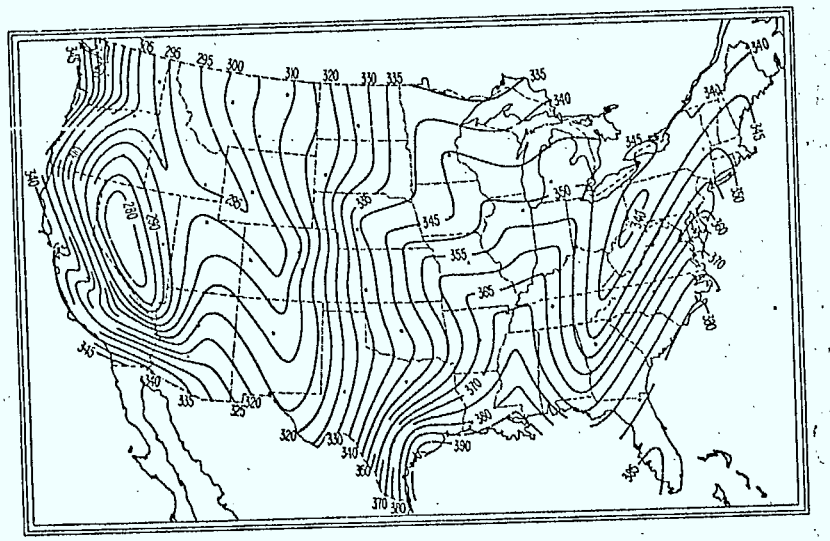


FIGURE 9.6. *Mean* N_0, *August 1400.*

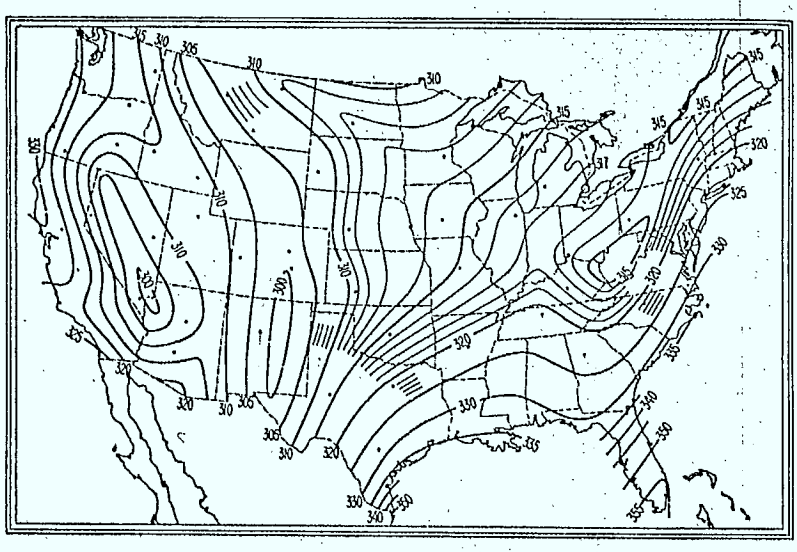


FIGURE 9.7. *Mean* N_0, *November 0200.*

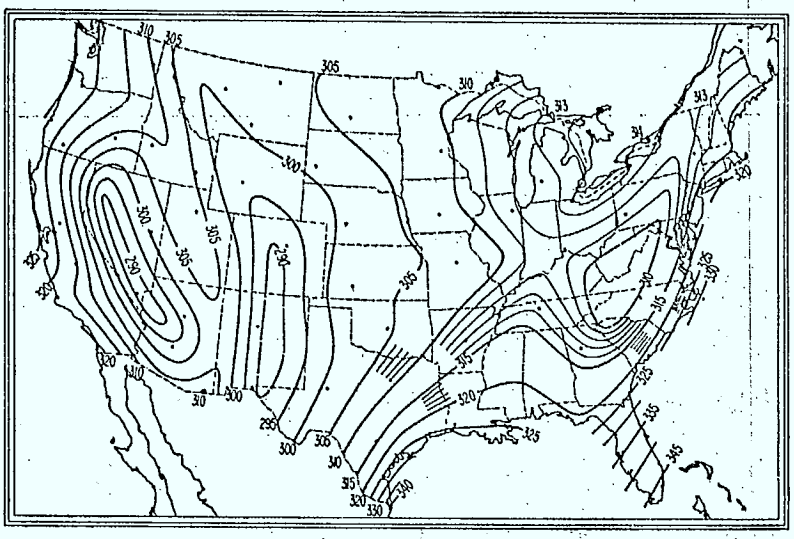


FIGURE 9.8. *Mean* N_0, *November 1400.*

MAPS ARE AVAILABLE FOR THE U.S.A. AND THE REST OF THE WORLD INDICATING THE MEAN REFRACTIVE INDEX AT SEA LEVEL ALTITUDE.

REFRACTIVE INDEX AT SEA LEVEL = N_o

REFRACTIVE INDEX AT ALTITUDE h_s = N_s

h_s IS IN THOUSANDS OF FEET

PAGE 15 SHOWS THE RELATIONSHIP BETWEEN THE REFRACTIVE INDEX AND THE SITE ALTITUDE FOR DIFFERENT N_o.

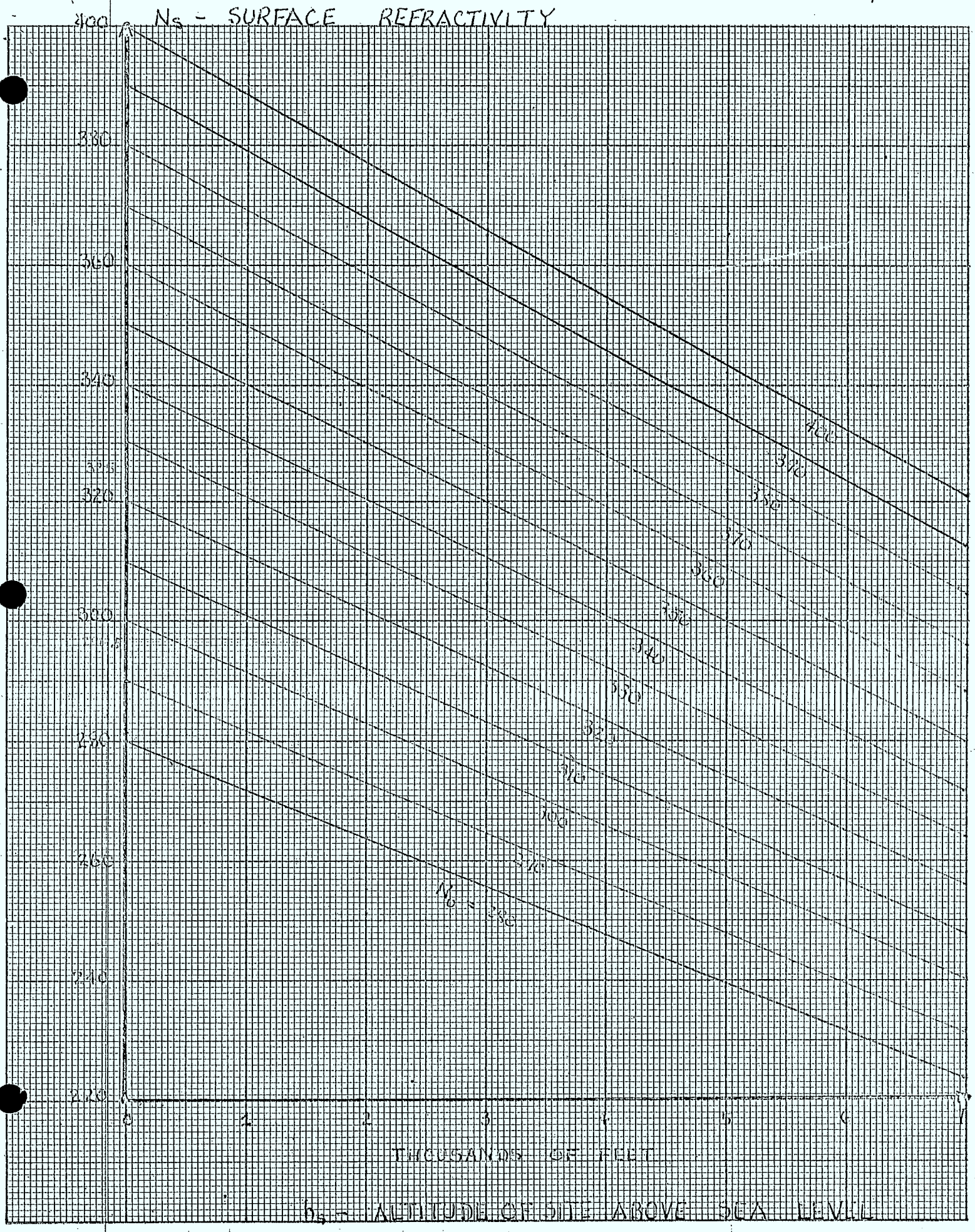
PAGE 16 RELATES THE REFRACTIVE WITH K.

EXAMPLE: - FIND THE RANGE OF THE MEAN VALUE OF K IN NEW BRUNSWICK FOR A SITE AT 1500 FEET ABOVE SEA LEVEL.

MEAN N_o VAIRES FROM 310 - 340

FOR h_s = 1.5, MEAN N_s VARIES FROM 296.5 - 325

MEAN K WILL VARY FROM 1.35 - 1.40 APP.

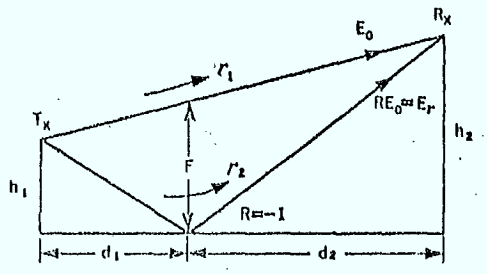

N_s - SURFACE REFRACTIVITY
400
380
360
340
320
300
280
260
240
220
0
1
2
3
4
5
6
7
THOUSANDS OF FEET
h_s - ALTITUDE OF SITE ABOVE SEA LEVEL

FRESNEL ZONES

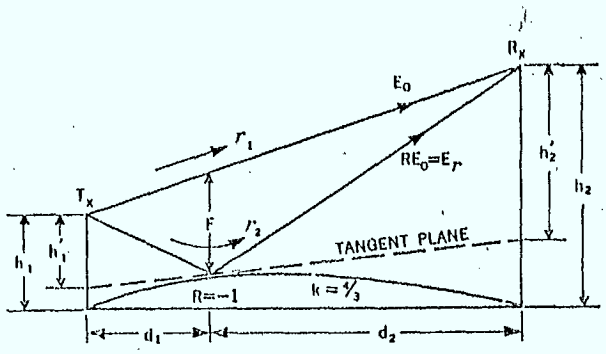
A RADIO WAVE CONSISTS OF A MULTITUDE OF RAYS. SOME OF THESE RAYS (DIRECT RAYS) WILL REACH THE RECEIVING ANTENNA WITHOUT REFLECTION WHILE OTHERS WILL REFLECT OFF THE TERRAIN.

THE REFLECTED RAY WILL ADD TO THE DIRECT RAY IF THEY ARE BOTH IN PHASE. IF NOT IN PHASE, THE REFLECTED RAY WILL SUBTRACT FROM THE DIRECT RAY AND COULD DESTROY THE SIGNAL COMPLETELY. DEPENDING ON THE DIFFERENCE IN THE PATH LENGTH BETWEEN THE DIRECT AND REFLECTED RAYS THE SIGNAL COULD BE STRENGTHENED OR WEAKENED.

REGIONS OF INCREASING POWER WILL FOLLOW REGION OF DECREASING POWER UNTIL AT SOME POINT THEY ARE BLOCKED BY AN OBSTACLE ON THE TERRAIN. THESE REGIONS ARE FRESNEL ZONES.

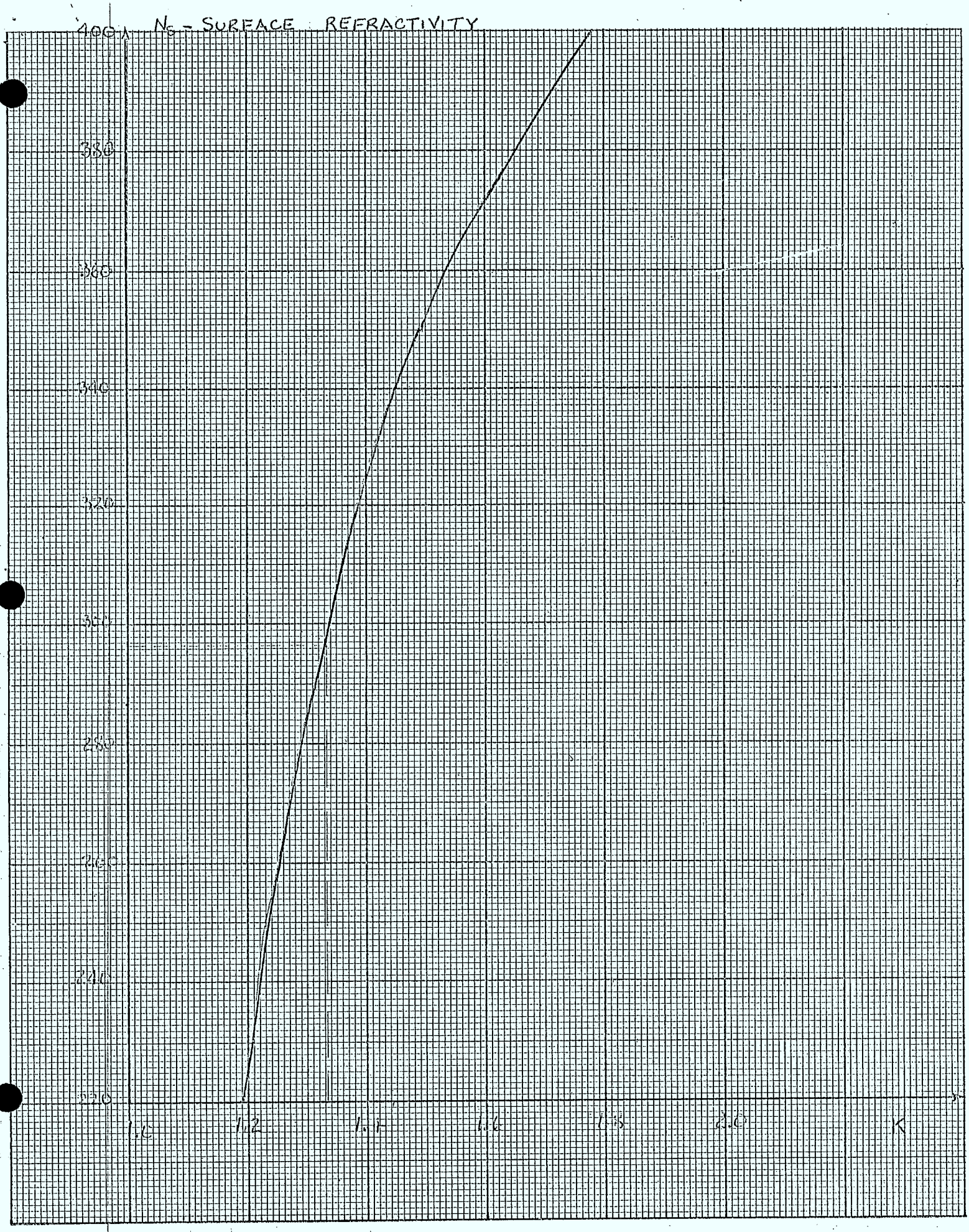


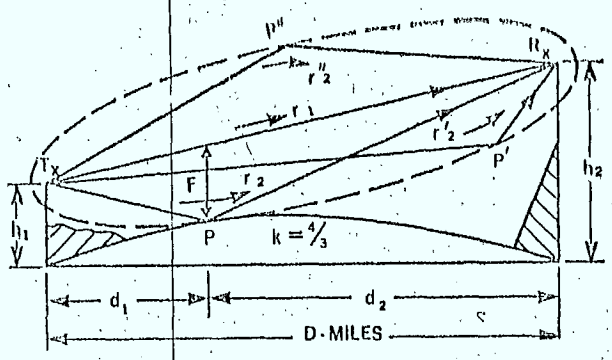
a) PLANE-EARTH CASE



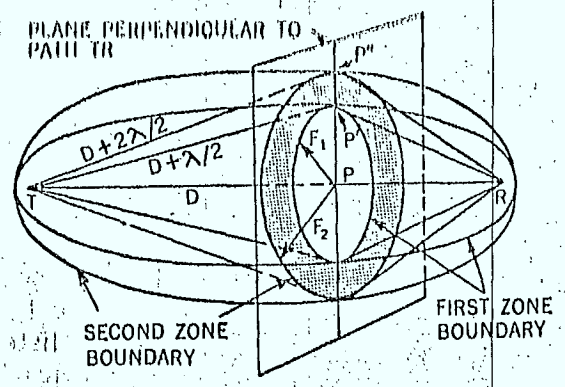
b) SMOOTH-SPHERE CASE

- Reflections From Plane Earth and Smooth Sphere

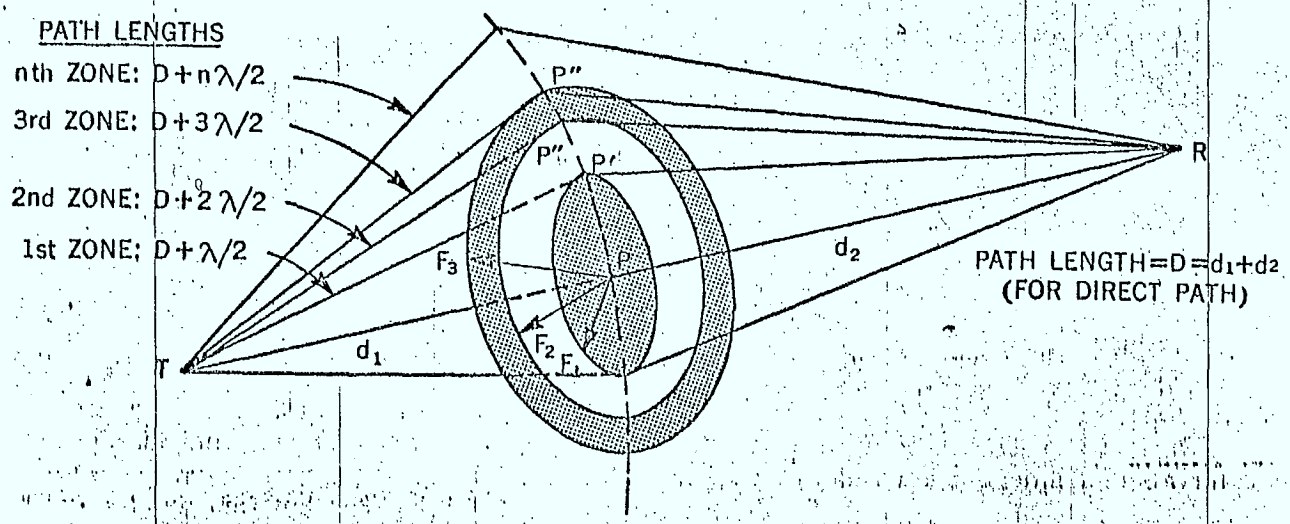

N_0 - SURFACE REFRACTIVITY
400
380
360
340
320
300
280
260
240
220
1.0
1.2
1.4
1.6
1.8
2.0
K



Fresnel-zone Radius on a Microwave Path



Representation of Fresnel Zones in Three Dimensions



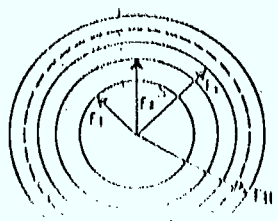
Cross Section of Radio Path, Showing Fresnel Zones

THE ODD FRESENL ZONES (1,3,5, - - - -) ARE ADDITIVE.
THE EVEN FRESNEL ZONES (2,4,6, - - - - -) ARE SUBTRACTIVE.
THIS NOTATION IDENTIFIES THE FRESNEL ZONES F_1, F_2, F_3 - - - - - .

$$F_1 = 131.5 \sqrt{\frac{\lambda\, d_1\, d_2}{D}} \text{ FEET}$$

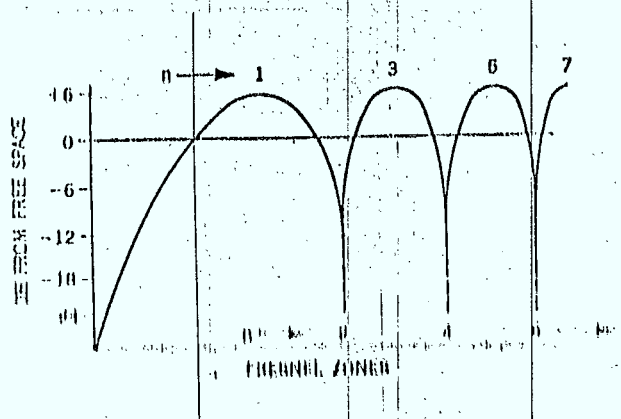
λ = WAVELENGTH IN METERS
D = PATH LENGTH IN MILES
d_1 = DISTANCE TO NEAR END OF PATH IN MILES
d_2 = DISTANCE TO FAR END OF PATH IN MILES

$F_2 = \sqrt{2}\, F_1$
$F_3 = \sqrt{3}\, F_1$
$F_4 = \sqrt{4}\, F_1$ etc. . . . .



$F_2 = \sqrt{2}\, F_1$
$F_3 = \sqrt{3}\, F_1$
- - - - - -
$F_n = \sqrt{n}\, F_1$

— Fresnel-zone Radii



— Signal Strength versus Fresnel Zones

Multiplying Factor For Determining F_n When F_1 Is Known. ($F_n = F_1\sqrt{n}$)

n	$\sqrt{n}$	n	$\sqrt{n}$	n	$\sqrt{n}$	n	$\sqrt{n}$	n	$\sqrt{n}$
1	1.000	16	4.000	31	5.568	46	6.782	61	7.810
2	1.414	17	4.123	32	5.657	47	6.856	62	7.874
3	1.732	18	4.243	33	5.745	48	6.928	63	7.937
4	2.000	19	4.359	34	5.831	49	7.000	64	8.000
5	2.236	20	4.472	35	5.916	50	7.071	65	8.062
6	2.449	21	4.583	36	6.000	51	7.141		
7	2.646	22	4.690	37	6.083	52	7.211		
8	2.828	23	4.796	38	6.164	53	7.280		
9	3.000	24	4.899	39	6.245	54	7.348		
10	3.162	25	5.000	40	6.325	55	7.416		
11	3.317	26	5.099	41	6.403	56	7.483		
12	3.464	27	5.196	42	6.481	57	7.550		
13	3.606	28	5.291	43	6.557	58	7.616		
14	3.742	29	5.385	44	6.633	59	7.681		
15	3.873	30	5.477	45	6.708	60	7.746		

EXAMPLE: - CALCULATE F_1, F_2 and F_{17} AT 4 GHz FOR A PATH 30 MILES LONG WITH AN OBSTRUCTION ON THE 10TH MILE.

$$F_1 = 131.5 \sqrt{\frac{\lambda d_1 d_2}{D}}$$

AT 4 GHz λ = .25 FEET

= .25 X .33 = .0825 METERS

$\sqrt{.0825}$ = .364

$$F_1 = 131.5 \times .364 \sqrt{\frac{d_1 d_2}{D}} = 36 \sqrt{\frac{d_1 d_2}{D}}$$

d_1 = 10 MILES

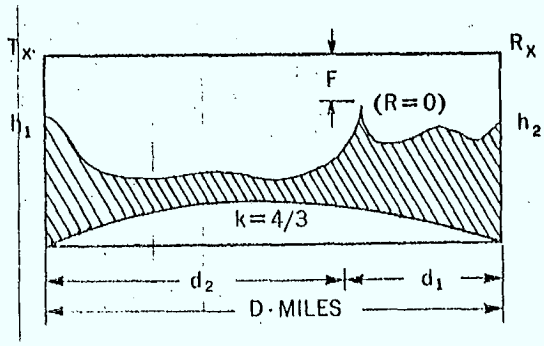
d_2 = 20 MILES

D = 30 MILES

$$F_1 = 36 \sqrt{\frac{10 \times 20}{30}} = 93 \text{ FEET}$$

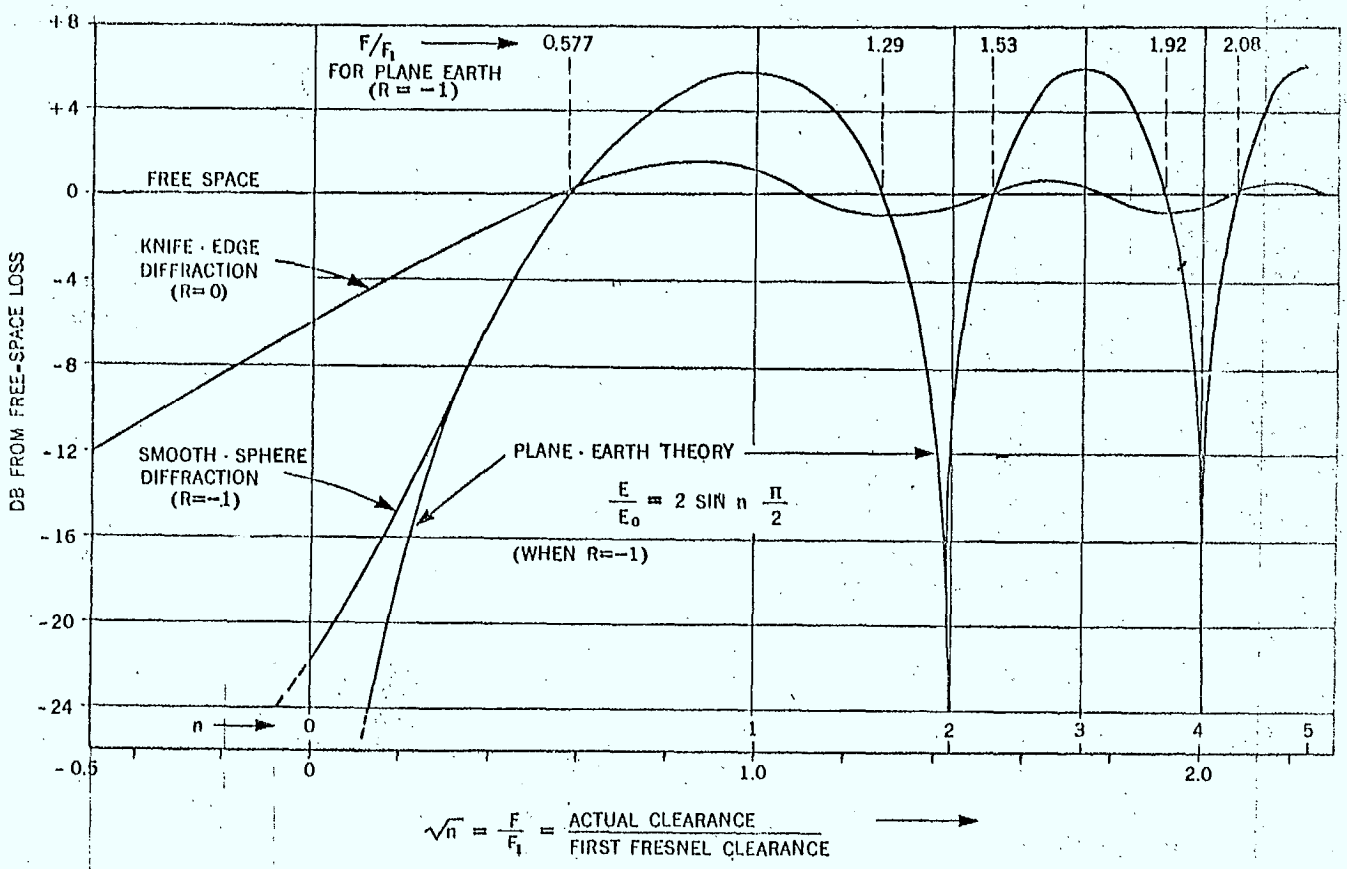
$$F_2 = \sqrt{2}\, F_1 = 1.414 \times 93 = 132 \text{ FEET}$$

$$F_{17} = \sqrt{17}\, F_1 = 4.123 \times 93 = 386 \text{ FEET}$$



TO CALCULATE THE NUMBER OF FRESNEL ZONES CLEARED ABOVE AN OBSTRUCTION

$$\left(\frac{F}{F_1}\right)^2 = n \quad \text{(NUMBER OF FRESNEL ZONES CLEARING THE OBSTRUCTION)}$$



– Effect of Path Clearance on Radio Transmission

REFLECTION COEFFICIENT

USUALLY A PORTION OF THE REFLECTED WAVE IS ABSORBED BY THE TERRAIN AT THE REFLECTION POINT.

THE AMOUNT OF THE REFLECTED WAVE ABSORBED WILL DEPEND ON THE CONDITION OF THE TERRAIN AT THE REFLECTION POINT (SMOOTH OR ROUGH). STILL WATER FOR EXAMPLE REFLECTS MOST OF THE WAVE WITHOUT ABSORBING MUCH OF IT.

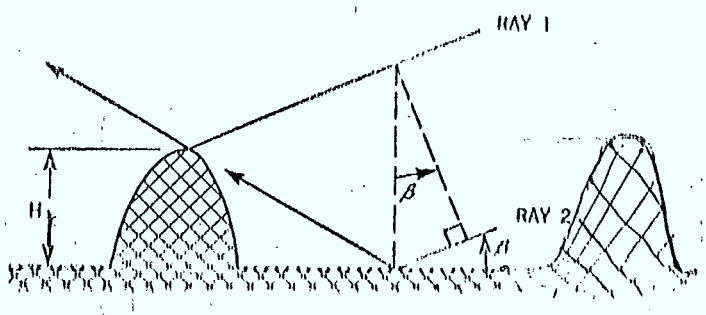
R = REFLECTION COEFFICIENT AND VARIES BETWEEN 0 AND -1

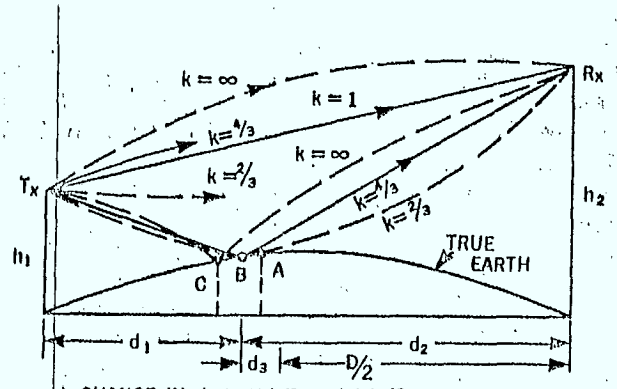
R = -1 MEANS THAT 100% REFLECTION OCCURS

R = 0 MEANS THAT 100% ABSORPTION OCCURS

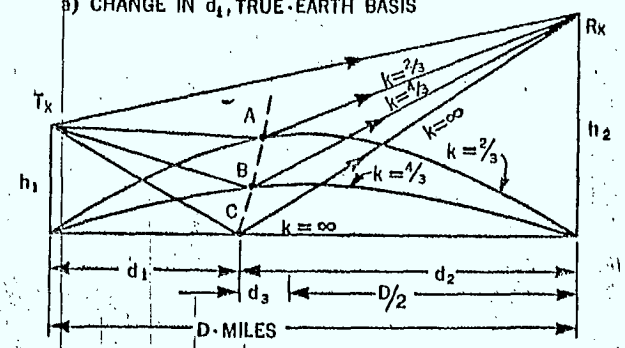
FOR A REFLECTING PATH THE HIGHER THE ABSOLUTE VALUE OF R THE DEEPER THE FADES AT THE EVEN FRESNEL ZONES, AND HIGHER GAINS WILL BE ACHIEVED AT ODD FRESNEL ZONES.

THE SIZE OF HUMPS (H) IN THE TERRAIN AT THE REFLECTION POINT WILL DETERMINE THE ROUGHNESS OF THE TERRAIN.





a) CHANGE IN d_1, TRUE-EARTH BASIS



b) CHANGE IN d_1, CORRECTED EARTH BASIS

Reflection Point versus "k"

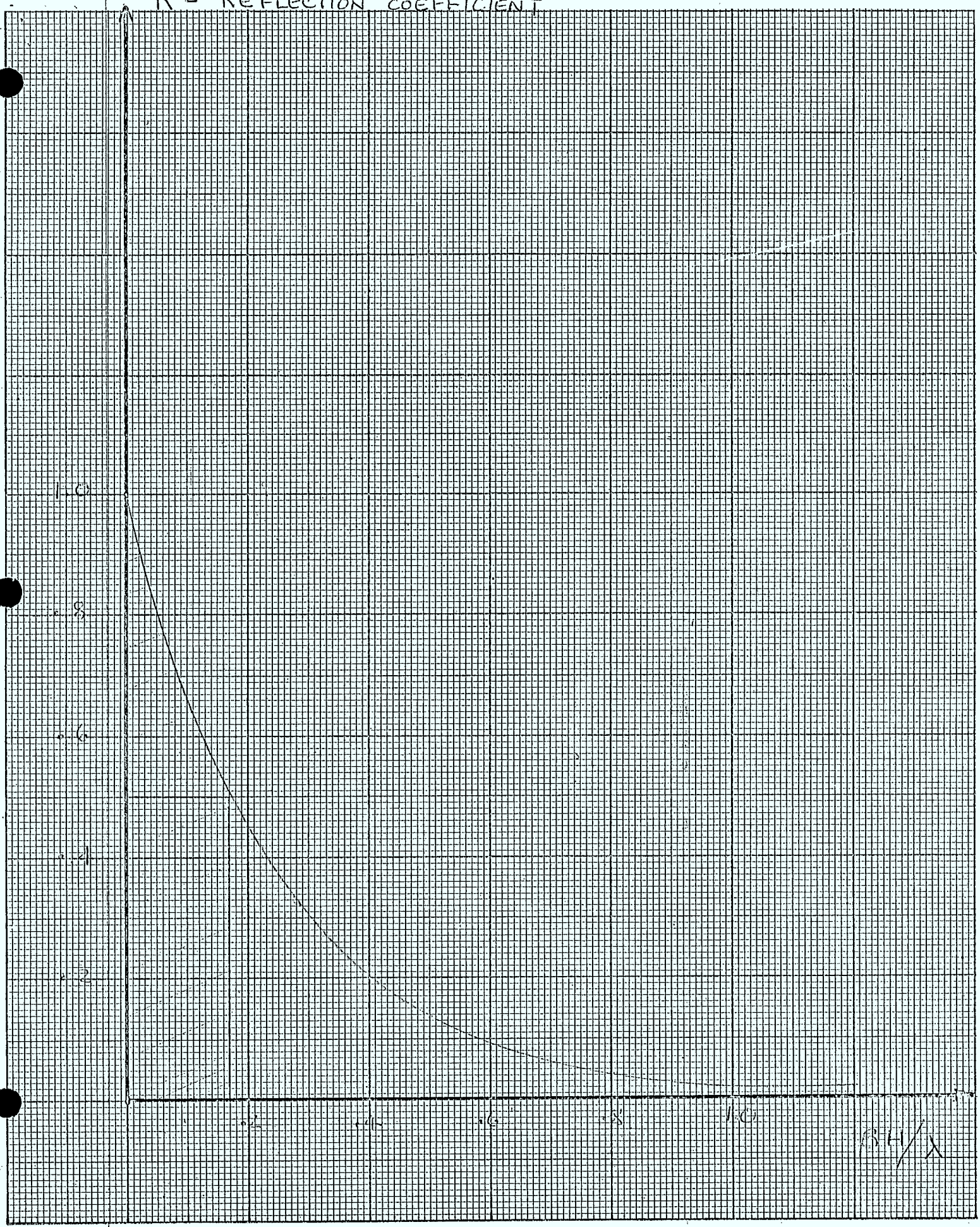
AS YOU CAN SEE THE POSITION OF THE REFLECTION (AND d_1) CHANGES WITH K.

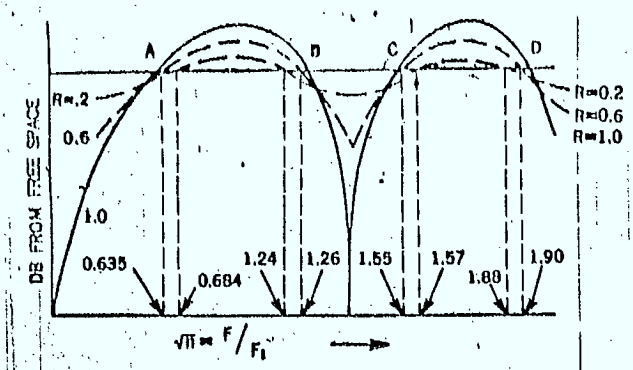
THE RELATIONSHIP BETWEEN THE SIZE OF THE HUMP (H) AND THE REFLECTION COEFFICIENT IS SHOWN ON PAGE 24, WHERE

λ = WAVELENGTH IN FEET

H = SIZE OF HUMPS FEET

$$B = \frac{1}{5280} \left(\frac{h_1}{d_1} - \frac{d_1}{1.5K} \right)$$


R - REFLECTION COEFFICIENT
1.0
.8
.6
.4
.2
.2
.4
.6
.8
1.0
βH/λ



Signal Strength versus Clearance When Reflection Coefficient Changes

Change in Free-space Cross-points with Reflection Coefficient, R

R	Point A n_A	Point B n_B	Values of F/F_1 for points A, B, C, etc, of Fig. 20 as R varies						
			A	B	C	D	E	F	G
1.0	.333	1.667	F/F_1 = .577	1.29	1.53	1.92	2.08	2.38	2.52
0.9	.351	1.649	.592	1.28	1.53	1.91	2.09	2.38	2.52
0.8	.369	1.631	.607	1.28	1.54	1.91	2.09	2.37	2.52
0.7	.386	1.614	.621	1.27	1.55	1.90	2.10	2.37	2.53
0.6	.403	1.597	.635	1.26	1.55	1.90	2.10	2.37	2.53
0.5	.420	1.580	.648	1.26	1.56	1.89	2.11	2.36	2.53
0.4	.436	1.564	.660	1.25	1.56	1.89	2.11	2.36	2.54
0.3	.452	1.548	.672	1.24	1.57	1.88	2.11	2.36	2.54
0.2	.468	1.532	.684	1.24	1.57	1.88	2.12	2.35	2.54
0.1	.484	1.516	.695	1.23	1.58	1.88	2.12	2.35	2.55
0	.500	1.500	.707	1.23	1.58	1.87	2.12	2.35	2.55

Note: $n_C = n_A + 2 = 2.333$, $n_B = n_C + 2 = 4.333$, etc. } See
$n_D = n_B + 2 = 3.667$, $n_E = n_D + 2 = 5.667$, etc. } points A, B, C, etc. ABOVE

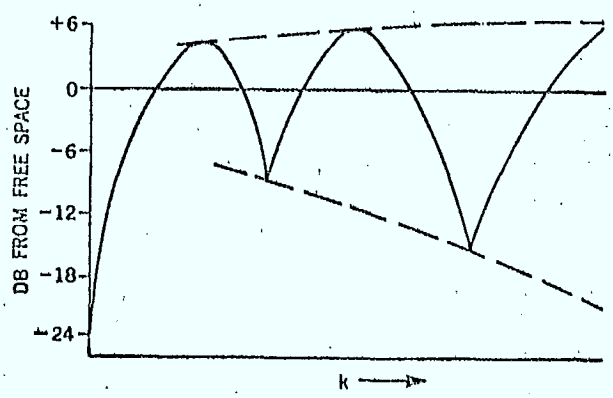
DIVERGENCE FACTOR

RAYS REFLECTED OFF A FLAT SURFACE ARE CONCENTRATED WITH LITTLE DIVERGENCE. WHILE RAYS REFLECTED OFF AN OUTWARDLY BENT SURFACE ARE SCATTERED WITH DIVERGENCE.

THIS MEANS THE HIGHER K IS, THE LESS DIVERGENCE THERE IS IN THE REFLECTED RAYS, IN TURN THIS WILL CAUSE DEEPER FADES AND HIGHER GAINS AT THE RECEIVING ANTENNA.

D_f = DIVERGENCE FACTOR

$$D_f = \frac{1}{\sqrt{1 + \frac{4d_1^2 d_2}{D(1.5\,Kh_1 - d_1^2)}}}$$



Effect of Divergence Factor

CLEARANCE CRITERIA FOR NON-REFLECTIVE PATHS

FOR "HEAVY ROUTE", HIGHEST-RELIABILITY SYSTEMS

AT LEASE $0.3F_1$ AT $K = 2/3$ AND $1.0F_1$ AT $K = 4/3$, WHICHEVER IS GREATER. IN AREAS OF VERY DIFFICULT PROPAGATION, IT MAY BE NECESSARY ALSO TO ENSURE A CLEARANCE OF AT LEAST GRAZING AT $K = 1/2$. (FOR 2 GH_Z PATHS ABOVE 36 MILES, SUBSTITUTE $0.6F_1$ AT $K = 1.0$).

NOTE THAT THE EVALUATION SHOULD BE CARRIED OUT ALONG THE ENTIRE PATH AND NOT JUST AT THE CENTER. EARTH BULGE AND FRESNEL ZONE RADII VARY IN A DIFFERENT WAY ALONG THE PATH, AND IT OFTEN HAPPENS THAT ONE CRITERION IS CONTROLLING FOR OBSTACLES NEAR THE CENTER OF THE PATH AND THE OTHER IS CONTROLLING FOR OBSTACLES NEAR ONE END OF THE PATH.

FOR "LIGHT-ROUTE" SYSTEMS WITH SLIGHTLY LESS STRINGENT RELIABILITY REQUIREMENTS.

AT LEAST $0.6F_1 + 10$ FEET AT $K = 1.0$.

AT POINTS QUITE NEAR THE ENDS OF THE PATHS, THE FRESNEL ZONES AND EARTH BULGE BECOME VANISHINGLY SMALL, BUT IT IS STILL NECESSARY TO MAINTAIN SOME MINIMUM OF PERHAPS 15 TO 20 FEET ABOVE ALL OBSTACLES.

EXAMPLE: - PAGE ~~29~~ 33 SHOWS A PATH PROFILE FOR A HOP ON A 4 GH_Z SYSTEM. FIND THE LOSS OR GAIN IN SIGNAL FROM F.S.L. LEVEL IF ANY AT THE RECEIVING ANTENNA FOR K = 4/3.

FOR K = 2/3 BULGE = $\frac{d_1 d_2}{1.5K}$

d_1 = 14 MILES

d_2 = 3 MILES

EARTH BULGE = $\frac{14 \times 3}{1}$ = 42 FEET

FIRST FRESNEL ZONE (F_1) = $131.5 \sqrt{\frac{\lambda d_1 d_2}{D}}$

FOR 4 GH_Z $F_1 = 36 \sqrt{\frac{d_1 d_2}{D}}$

D = 17 MILES

$F_1 = 36 \sqrt{\frac{14 \times 3}{17}}$ = 57 FEET

$.3F_1$ = 17.1 FEET

TOTAL CLEARANCE REQUIRED = 42 + 17.1 = 59.1 FEET

FOR K = 4/3 EARTH BULGE = $\frac{14 \times 3}{2}$ = 21 FEET

F_1 = 57 FEET

TOTAL CLEARANCE REQUIRED = 21 + 57 = 79 FEET

79 FEET > 59.1 FEET

TOTAL CLEARANCE = 79 FEET + 30 FEET FOR TREES = 109 FEET

FOR THE DASHED LINES (see page 32)

h_1 = 150 FEET h_2 = 285 FEET D = 17 MILES

$A = \frac{150}{(17)^2} = .52$ $B = \frac{285}{(17)^2} = .97$

FOR K = INFINITY n = .345 d_1 = 5.86 MILES (D x n)

K = 4/3 n = .365 d_1 = 6.2 MILES

K = 1 n = .37

K = 2/3 n = .382 d_1 = 6.5 MILES

AS WE CAN SEE THE REFLECTION POINT IS OVER THE WATER, THE WORST POSSIBLE CONDITION, SINCE R COULD BE -1.

IF WE CHANGE THE ANTENNA HEIGHTS AS SHOWN BY THE SOLID LINE

h_1 = 260 FEET h_2 = 260 FEET

$A = \frac{260-30}{(17)^2} = .795$ $B = \frac{260-30}{(17)^2} = .795$

FOR ALL K n = .5 d_1 = 8.5 MILES

<u>REFLECTION COEFFICIENT</u>

$$B = \frac{1}{5280}\left(\frac{h_1}{d_1} - \frac{d_1}{1.5K}\right)$$

$$= \frac{1}{5280}\left(\frac{230}{8.5} - \frac{8.5}{2}\right)$$

$$= 4.35 \times 10^{-3}$$

H = 16 FEET

λ = .25 FEET

$$BH/\lambda = 4.35 \times 10^{-3} \times 16/.25 \doteq .278$$

FROM PAGE 24

FOR $BH/\lambda = .278$ $\qquad$ $R = .33$

DIVERGENCE FACTOR

$K = 4/3$

$$D_f = \frac{1}{\sqrt{1 + \frac{4\, d_1^2\, d_2}{D\,(1.5\, Kh_1 - d_1^2)}}}$$

$$= \frac{1}{\sqrt{1 + \frac{4 \times 72 \times 8.5}{17\,(2 \times 230 - 72)}}} = .855$$

CLEARANCE ABOVE REFLECTION POINT

FROM PROFILE DRAWING F = 195 FEET

$$F_1 = 36\sqrt{\frac{d_1\, d_2}{D}} = 75 \text{ FEET}$$

$$\frac{F}{F_1} = \frac{195}{75} = 2.6 = \sqrt{n}$$

$n = 6.75$

LEVEL FROM FREE SPACE = $10 \text{ LOG } \left(1 + (RD_f)^2 + 2RD_f \cos (n-1)\,\pi\right)$

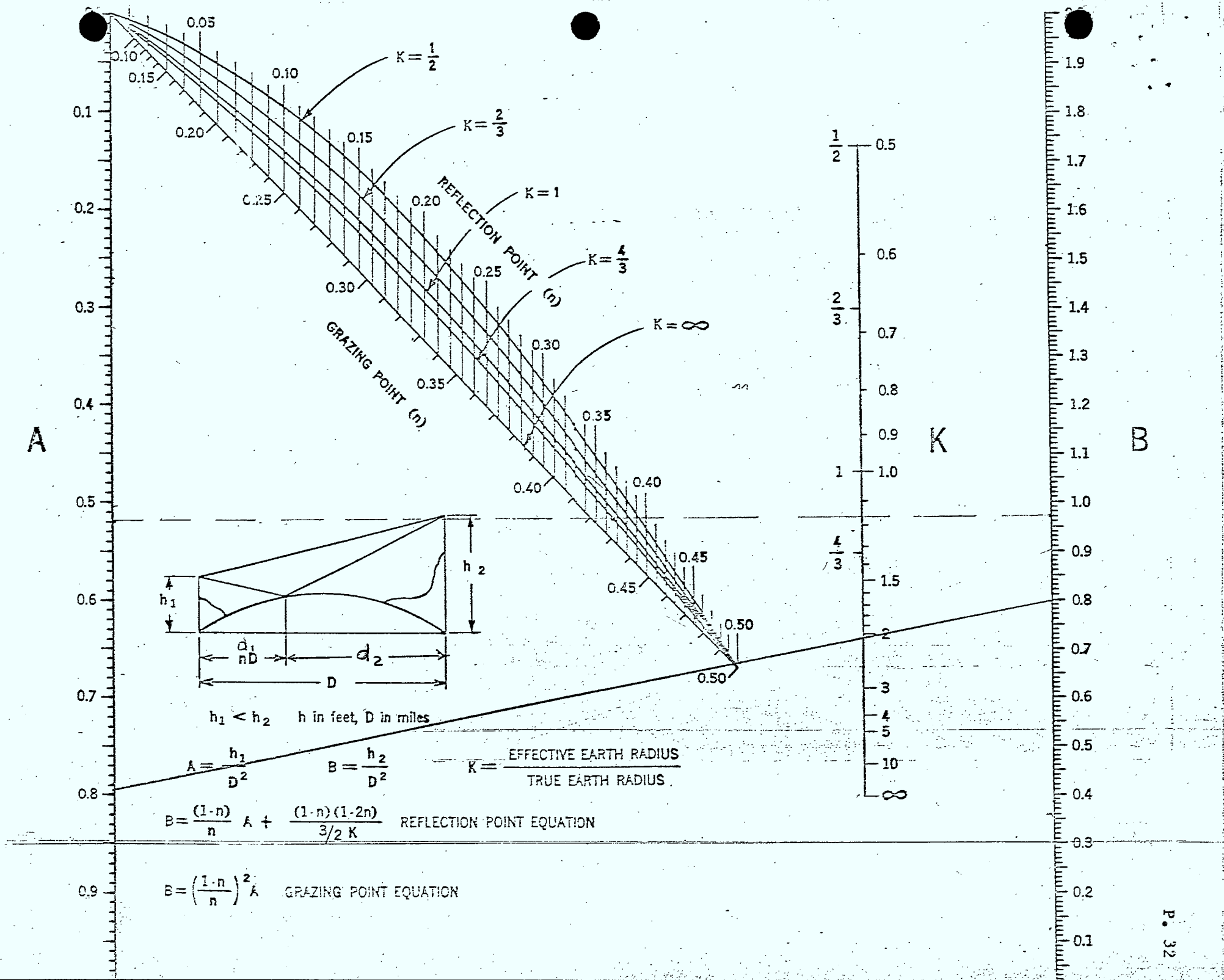
n = FRESNEL ZONE

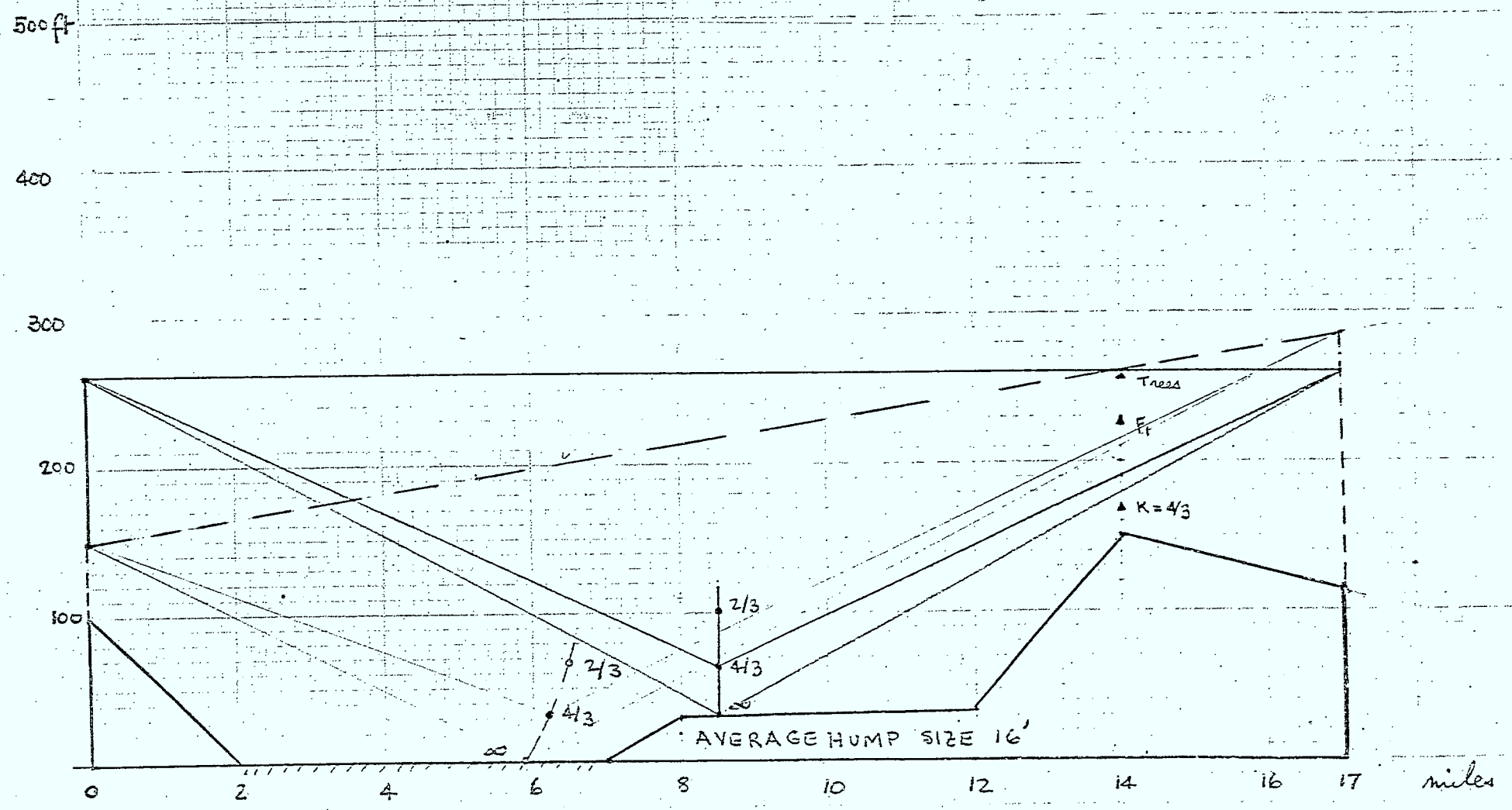
LEVEL FROM F.S =

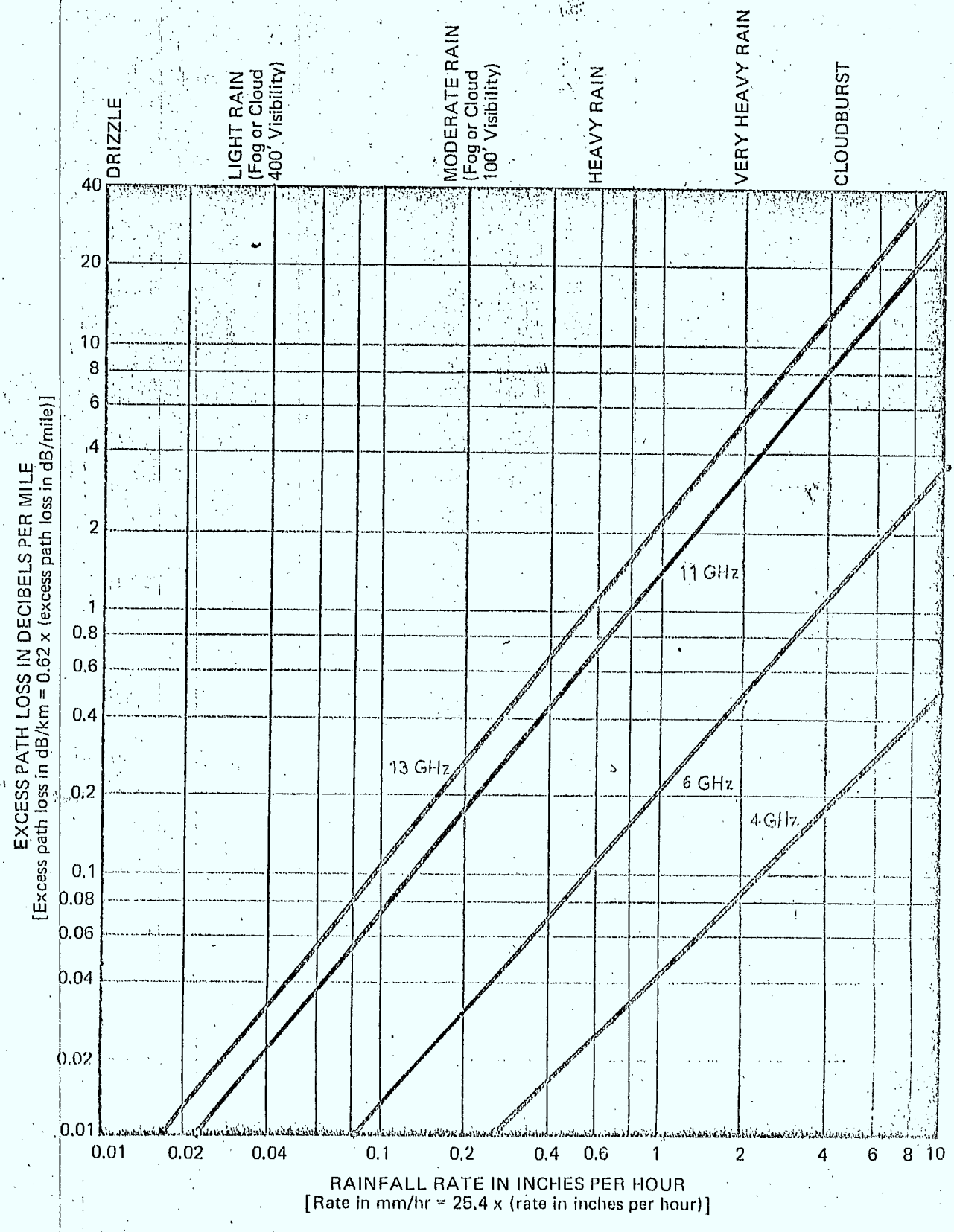
$$10 \text{ LOG } \left[1 + (.33 \times .855)^2 + 2(.33 \times .855) \cos (6.75 - 1) \pi \right]$$

$$= 10 \text{ LOG } \left[1 + .08 + .57 \cos (5.75 \pi) \right]$$

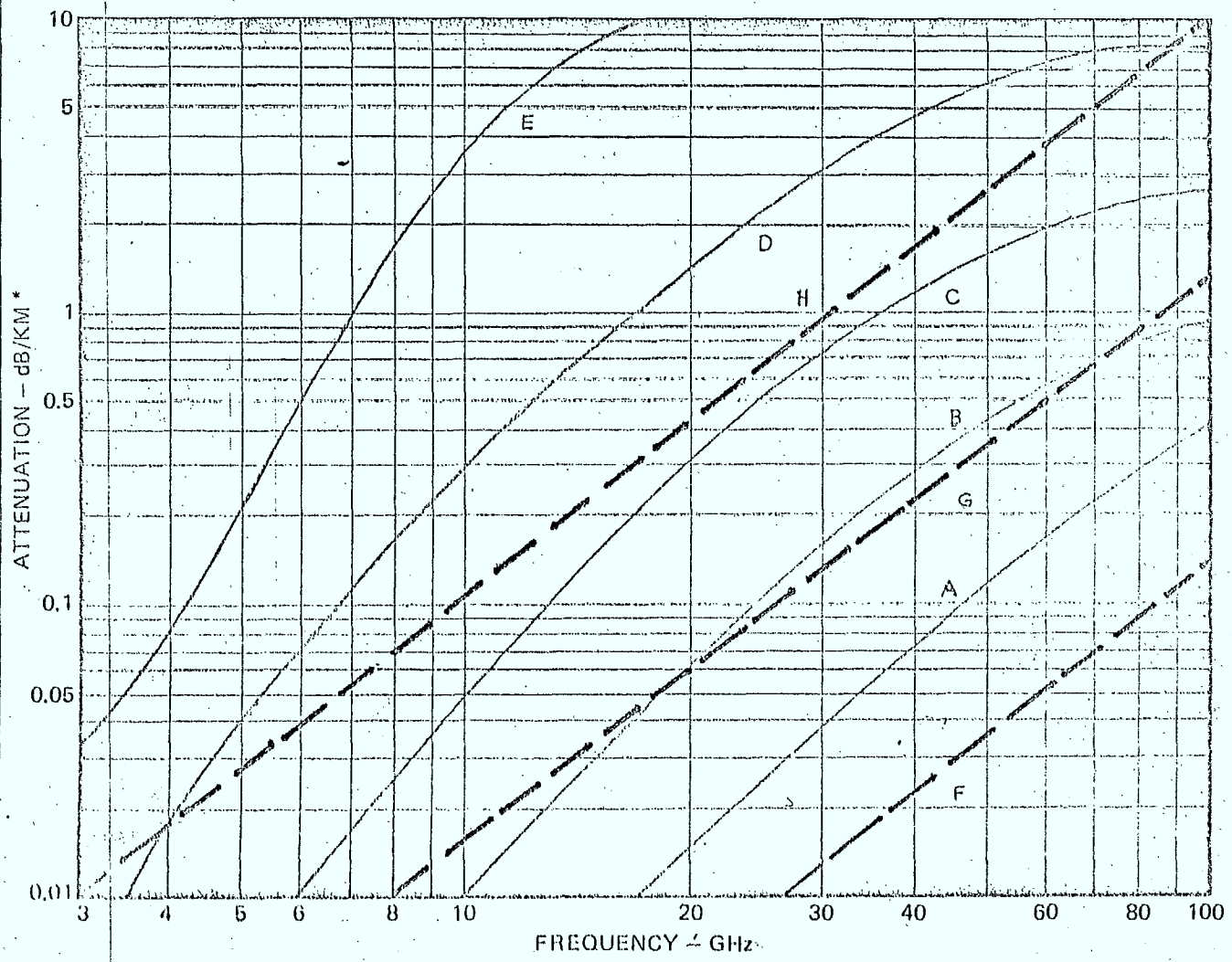
$$= 10 \text{ LOG } \left[1 + .08 + .57 \cos 1.75 \pi \right] = + 1.7 \text{ db.}$$


A
B
K
REFLECTION POINT (n)
GRAZING POINT (n)
K = 1/2
K = 2/3
K = 1
K = 4/3
K = ∞
h1
h2
d1
nD
d2
D
h1 < h2 h in feet, D in miles
A = h1/D² B = h2/D² K = EFFECTIVE EARTH RADIUS / TRUE EARTH RADIUS
B = (1-n)/n A + (1-n)(1-2n)/(3/2 K) REFLECTION POINT EQUATION
B = ((1-n)/n)² A GRAZING POINT EQUATION


500 ft
400
300
200
100
0
2
4
6
8
10
12
14
16
17
miles
Tness
F_f
K = 4/3
2/3
4/3
2/3
4/3
∞
∞
AVERAGE HUMP SIZE 16'



Rain Attenuation vs. Rainfall Rate (Theoretical, after Ryde and Ryde)



Attenuation in rainfall intensity of:

A, 0.25 mm/hr (drizzle) – .01 in/hr
B, 1.0 mm/hr (light rain) – .04 in/hr
C, 4.0 mm/hr (moderate rain) – .16 in/hr
D, 16 mm/hr (heavy rain) – .64 in/hr
E, 100 mm/hr (very heavy rain) – 4.0 in/hr

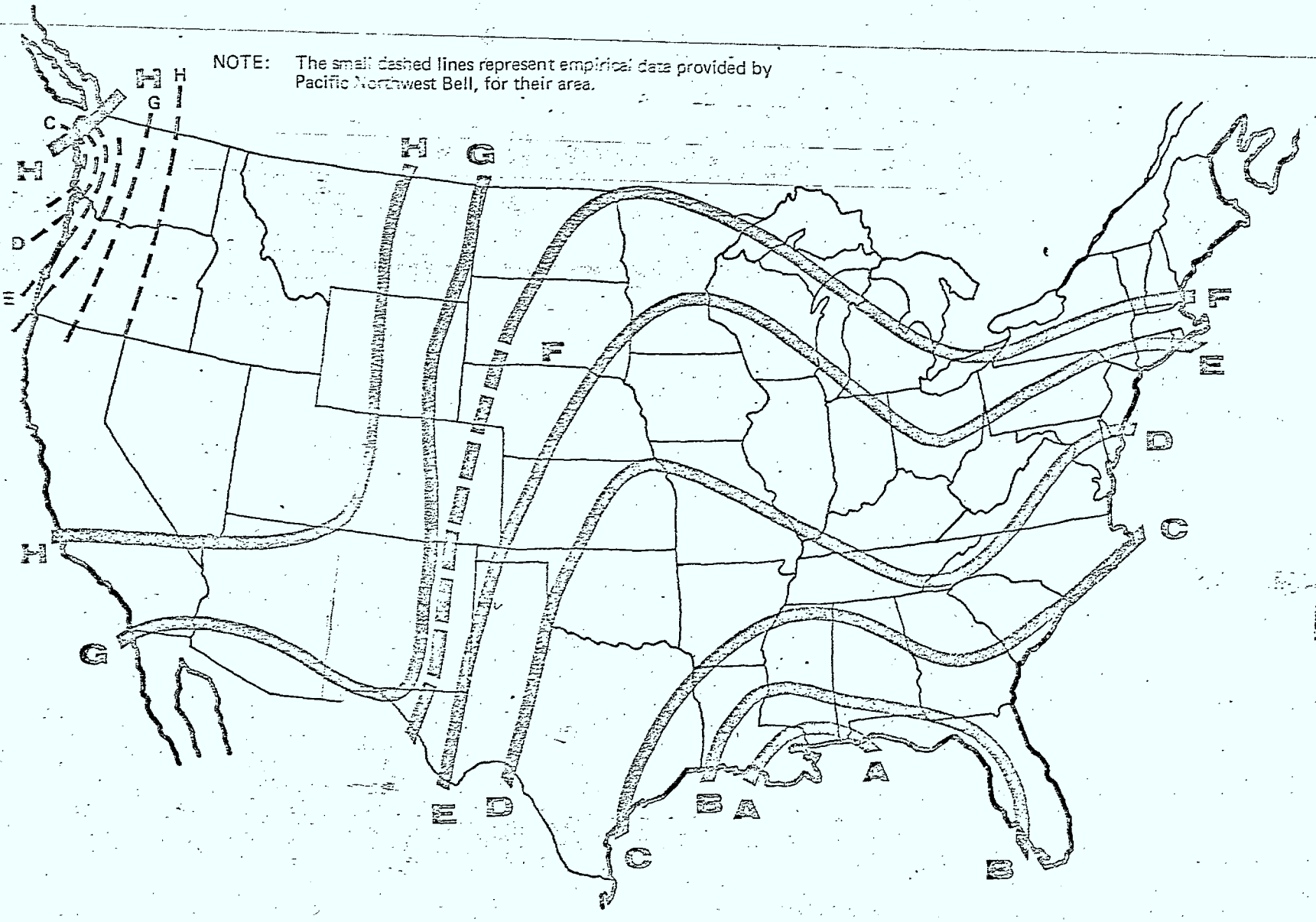
Attenuation in fog or cloud:

F, 0.032 gm/m^3 (visibility greater than 600 meters)
G, 0.32 gm/m^3 (visibility about 120 meters)
H, 2.3 gm/m^3 (visibility about 30 meters)

*Attn – dB/mile = 1.61 x (Attn in dB/km)

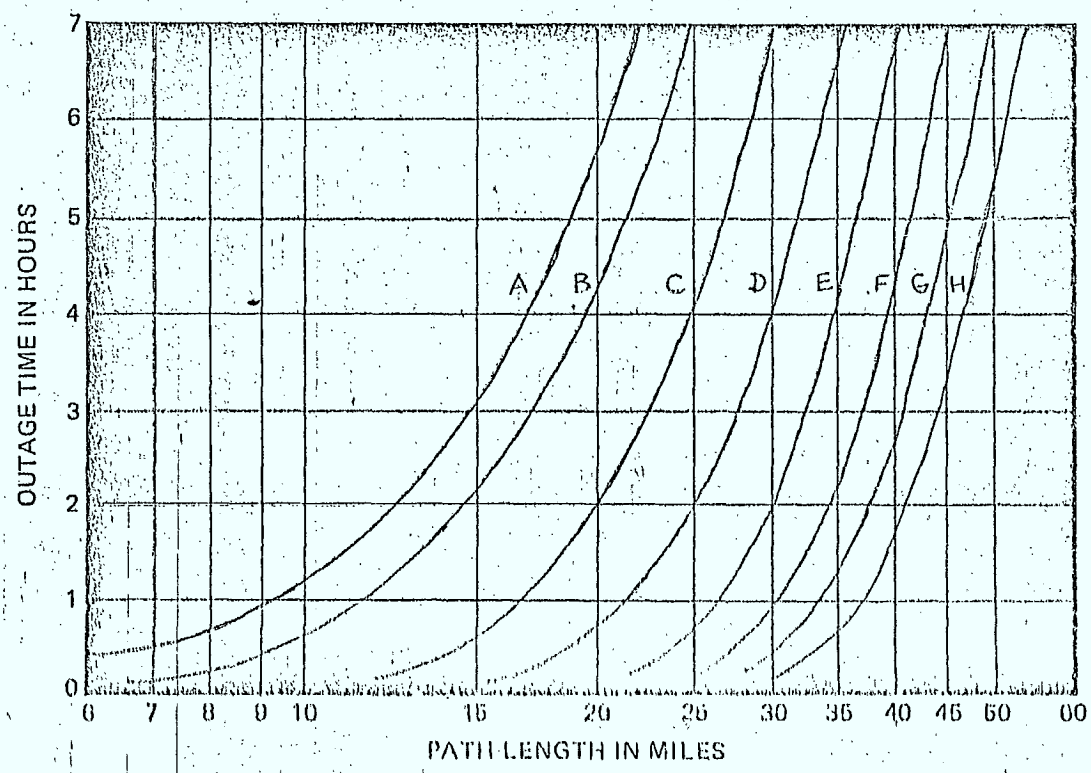
Attenuation Due To Precipitation (after CCIR)

Reproduced by permission IEEE Transaction Paper No. 55-1236 (Hathaway and Evans)



Contours Of Constant Path Length For Fixed Outage Time.

Reproduced by permission IEEE Transaction Paper No. 58-1236 (Hathaway and Evans)



Expected Outage Time In Hours Per Year vs. Path Length In Miles For Various Areas of the United States. (Based on 11 GHz paths with 40 dB fade margin; for 13 GHz paths, reduce path lengths by 30%. For 45 dB fade margin, decrease outage time by 15%; for 35 dB fade margin, increase it by 25%.)

Excess Attenuation Due To Atmospheric Absorption

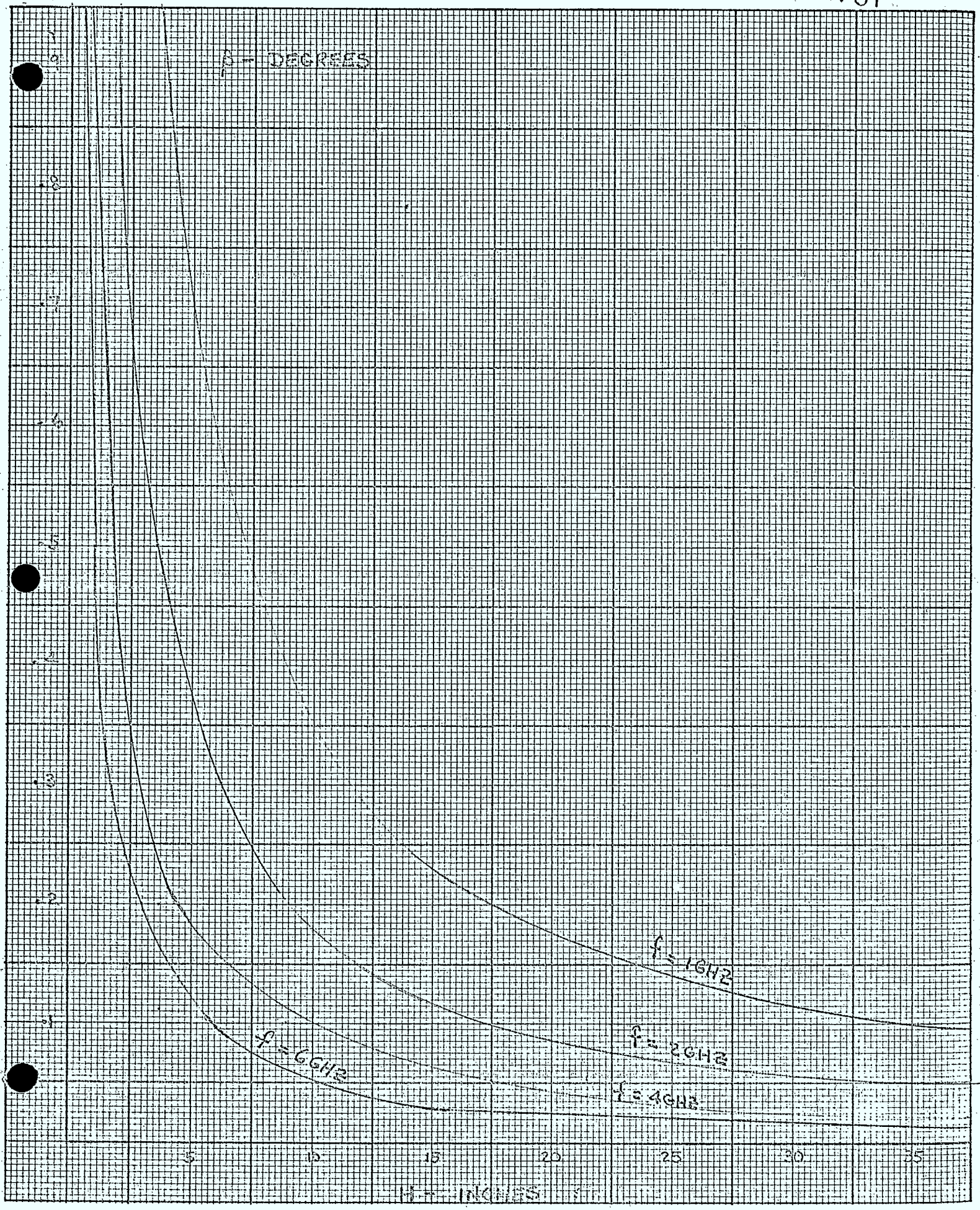
PATH LENGTH MILES	ATTENUATION – dB				
	2-4-6 GHz	8 GHz	10 GHz	12 GHz	14 GHz
20	0.20	0.26	0.32	0.38	0.48
40	0.40	0.52	0.64	0.76	0.96
60	0.60	0.78	0.96	1.14	1.44
80	0.80	1.04	1.28	1.52	1.92
100	1.00	1.30	1.60	1.90	2.40

RAYLEIGH ROUGHNESS CRITERION: -

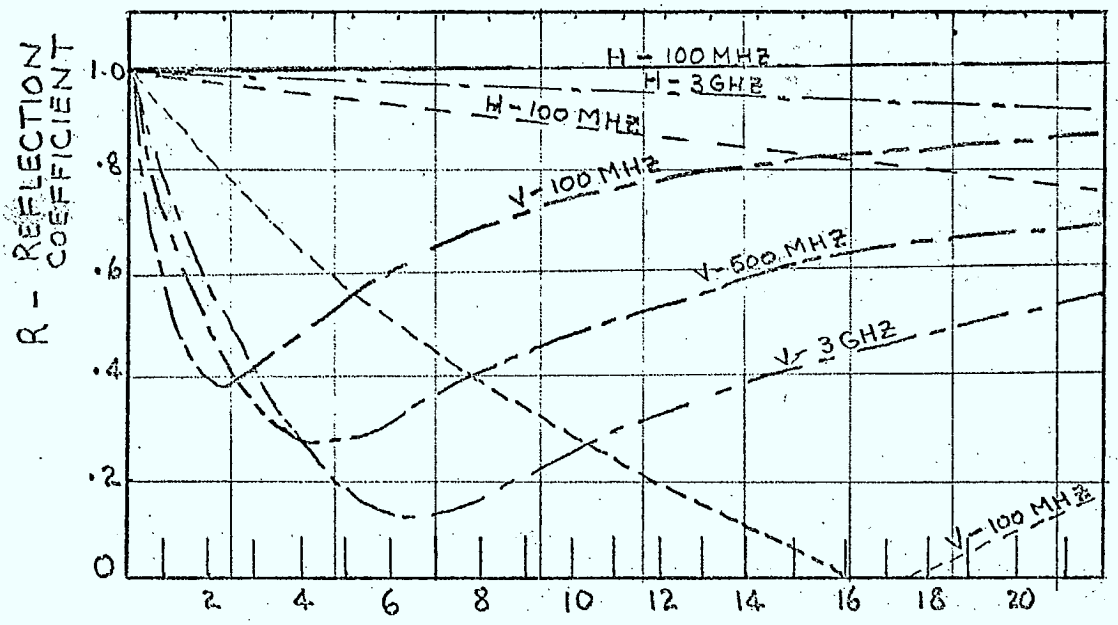
PAGE 39 SHOWS THE SIZE OF HUMPS (H) NEEDED AT THE REFLECTION POINT TO REMOVE THE THREAT OF A HARMFUL REFLECTION. YOU CAN NOTICE THAT THE HIGHER THE FREQUENCE THE SMALLER IS THE SIZE OF THE HUMPS (H) NEEDED FOR THAT PURPOSE.

POLARIZATION: -

PAGE 40 INDICATED THE RELATIONSHIP BETWEEN THE POLARIZATION OF THE TRANSMITTED WAVE AND THE REFLECTION COEFFICIENT FOR REFLECTIONS OF THE WAVE OCCURING ON SEA WATER OR DRY SOIL. THE GRAPH ON PAGE 40 INDICATES THAT FOR OVERWATER PATHS A VERTICALLY POLARIZED SIGNAL WILL MINIMIZE THE AMPLITUDE OF THE REFLECTED WAVE. HENCE IT IS RECOMMENDED FOR OVERWATER PATHS TO USE THE VERTICAL POLARIZATION.



335-5006 20 x 20



β - DEGREES

REFLECTION ANGLE

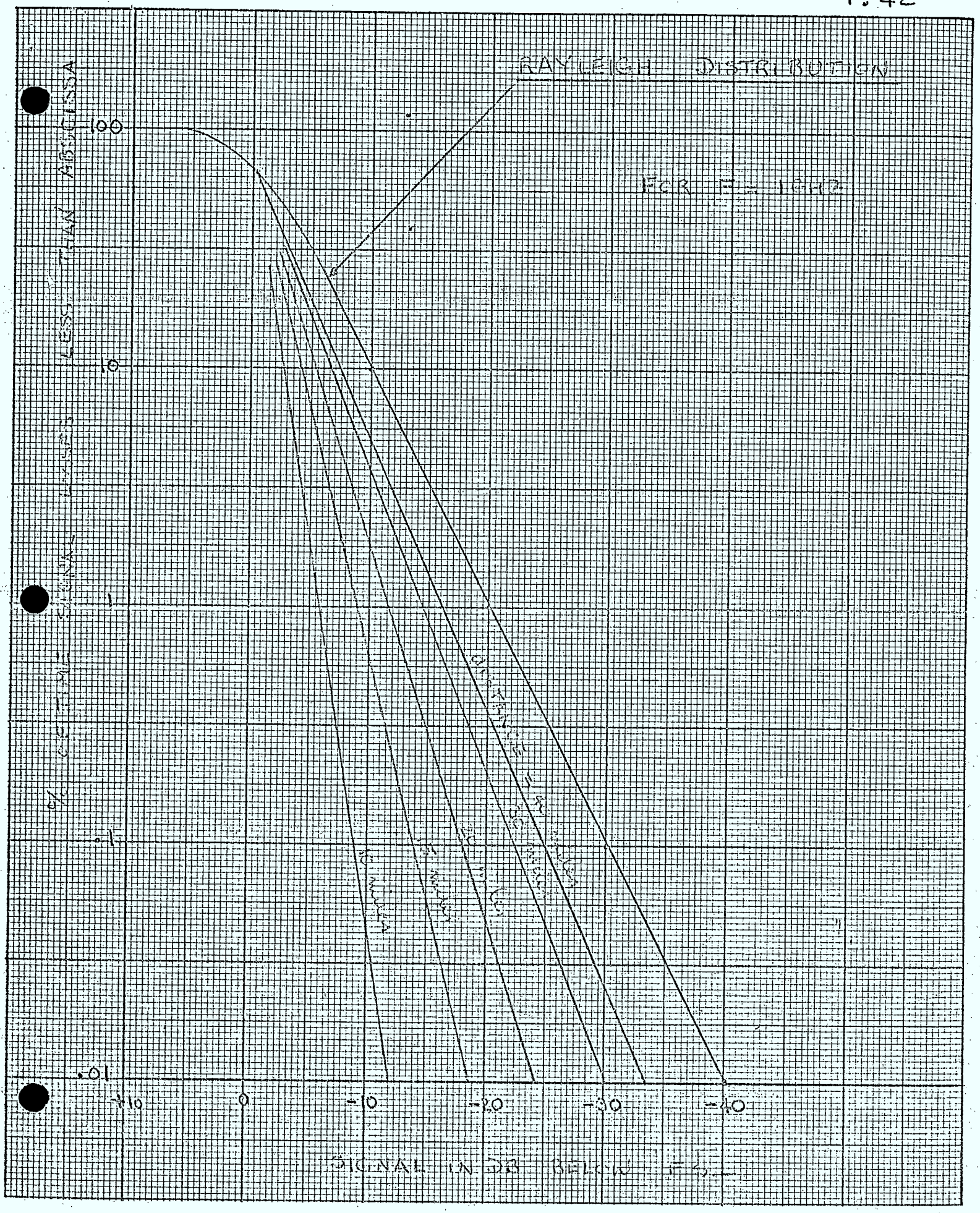
——— SEA WATER

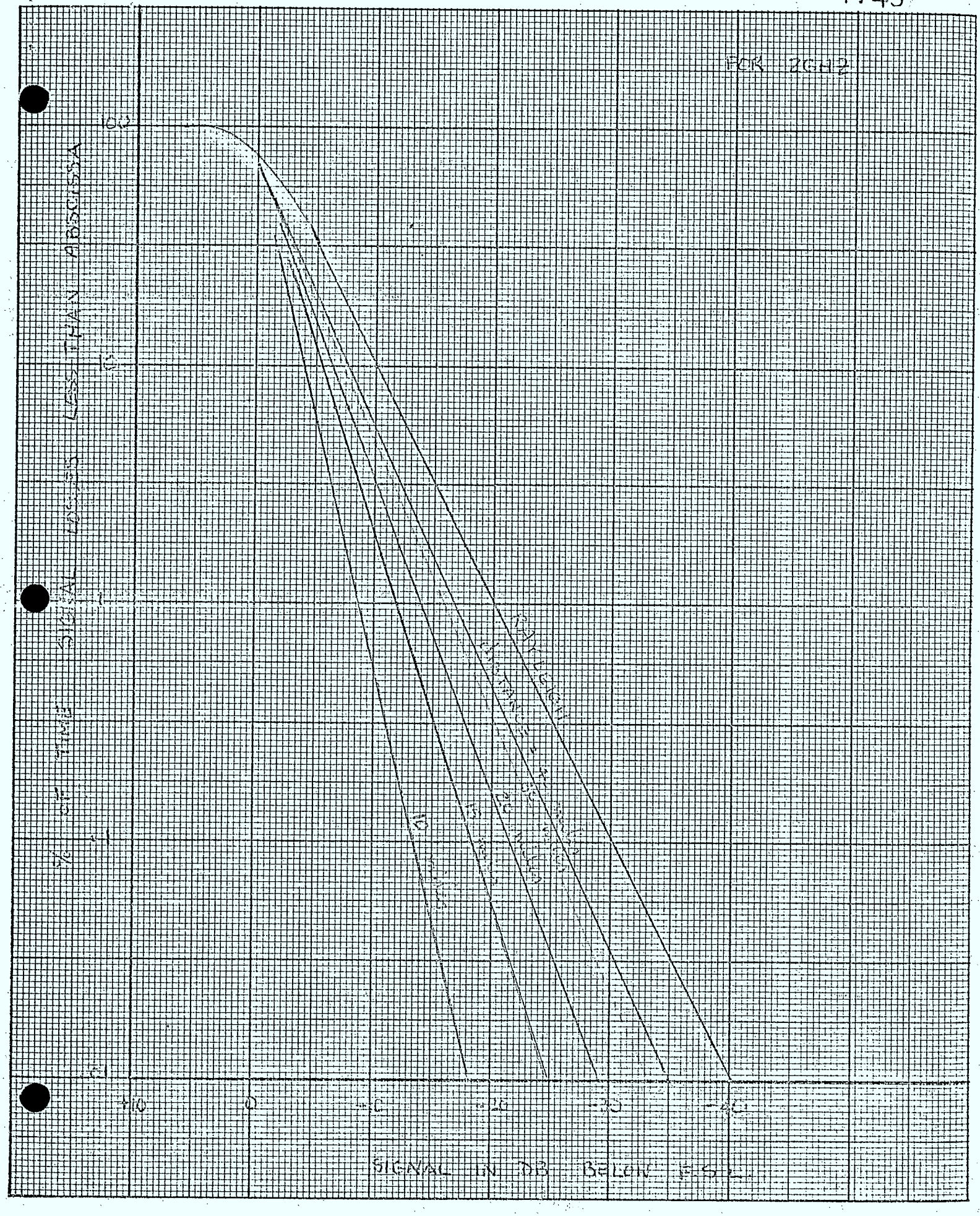
— — — DRY SOIL

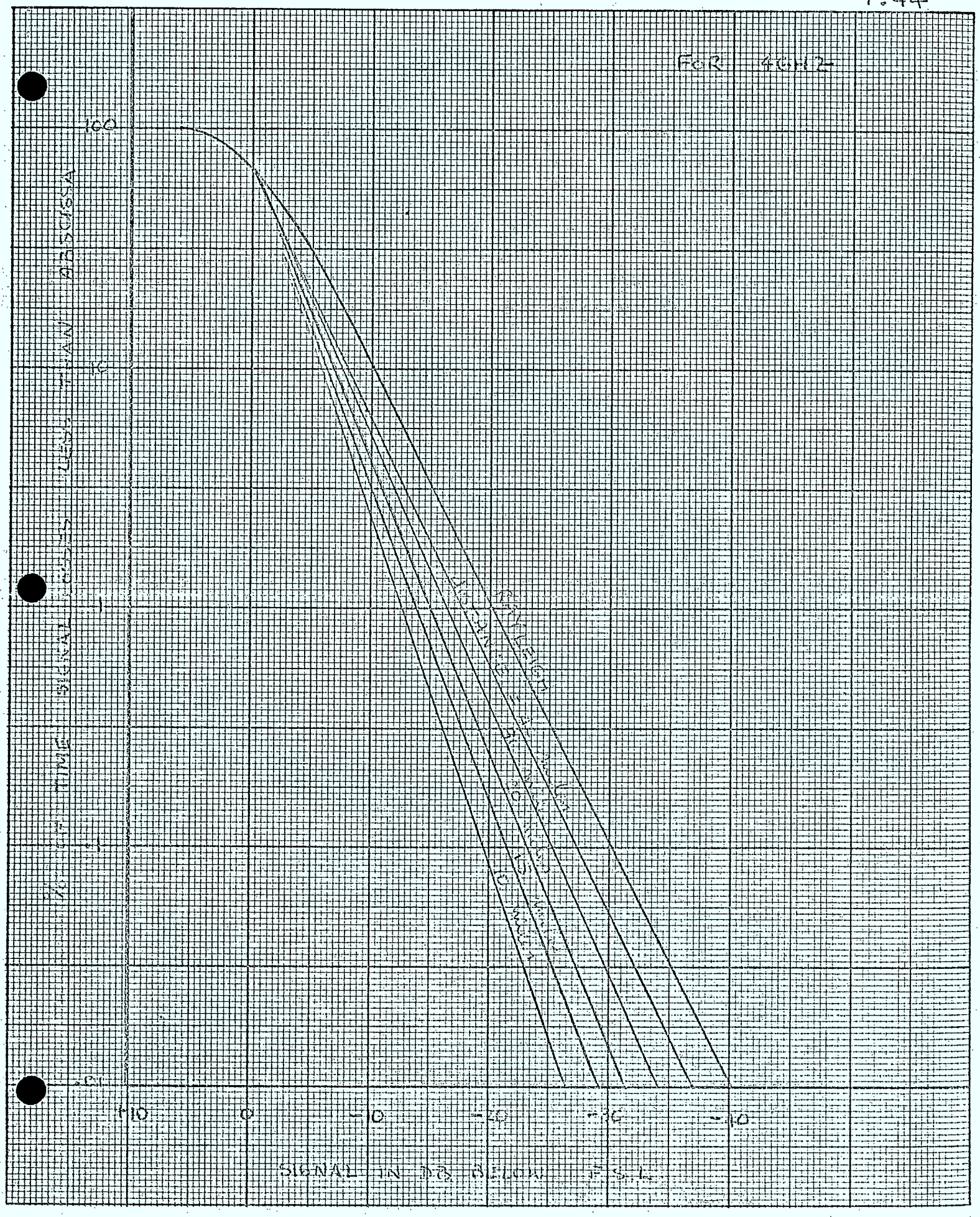
RELIABILITY OF A MICROWAVE PATH: -

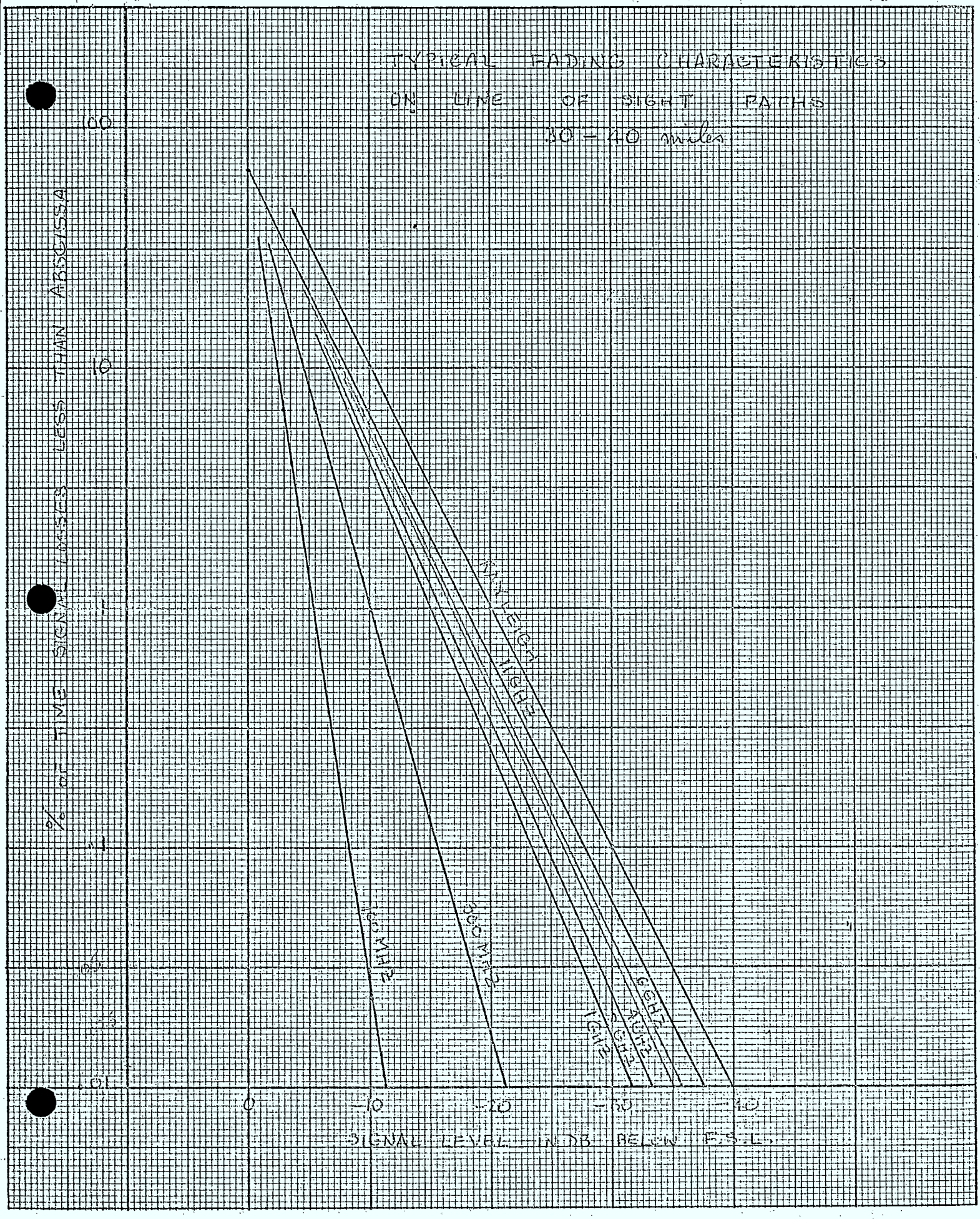
THE RELIABILITY OF A MICROWAVE PATH IS DESCRIBED BY THE PERCENTAGE OF TIME THAT THE RECEIVED SIGNAL LEVEL WILL NOT FADE BY MORE THAN 40DB. BELOW THE NOMINAL RECEIVED SIGNAL LEVEL. THE WORST FADE CONDITION IS DESCRIBED BY A FUNCTION CALLED THE "RAYLEIGH DISTRIBUTION". ACCORDING TO THE RAYLEIGH DISTRIBUTION 99.99% OF THE TIME THE FADE IN THE RECEIVED SIGNAL LEVEL FOR A MICROWAVE PATH SHOULD NOT BE MORE THAN 40DB.

PAGES 42, 43, 44 INDICATE THE RELIABILITY FOR DIFFERENT PATH LENGTHS AT $1GH_Z$, $2GH_Z$, AND 4 GH_Z RESPECTIVELY. BY STUDYING THE GRAPH ON PAGE 45, YOU CAN NOTE THAT THE HIGHER THE FREQUENCY THE WORSE THE RELIABILITY OF THE PATH. IT SHOULD BE EMPHASIZED THAT THE RELIABILITY OF THE PATH MENTIONED ABOVE IS THE PROPAGATION RELIABILITY ONLY AND DOES NOT INCLUDE THE EQUIPMENT RELIABILITY.


RAYLEIGH DISTRIBUTION
FOR E = 1GHZ
% OF TIME SIGNAL LEVELS LESS THAN ABSCISSA
100
10
1
.1
.01
-10
0
-10
-20
-30
-40
SIGNAL IN DB BELOW FS


FOR 2GHZ
% OF TIME SIGNAL LESS THAN ABSCISSA
100
10
1
0.1
+10
0
-10
-20
-30
-40
SIGNAL IN DB BELOW FSL


FOR 4GHZ
100
10
1
.1
.01
TIME SIGNAL EXCEEDS LEVEL ABSCISSA
+10
0
-10
-20
-30
-40
SIGNAL IN DB BELOW FSL


TYPICAL FADING CHARACTERISTICS
ON LINE OF SIGHT PATHS
30 = 40 miles
% OF TIME SIGNAL EXCEEDS LESS THAN ABSCISSA
100
10
1
.1
.01
0
-10
-20
-30
-40
SIGNAL LEVEL IN DB BELOW F.S.L.
2 GHz
1 GHz
400 MHz
200 MHz

TO CALCULATE THE TOTAL RELIABILITY OF A MULTIHOP SYSTEM, USE THE MONOGRAM ON PAGE 47.

THE BELL SYSTEM TOTAL RELIABILITY OBJECTIVE IS 99.98%. THIS OBJECTIVE APPLIES FOR THE TWO-WAY ANNUAL OUTAGE ON A LONG-HAUL SYSTEM (4000 MILES LONG) OR A SHORT-HAUL SYSTEM (250 MILES LONG).

TO ACHIEVE THIS OVERALL OBJECTIVE PROTECTION CHANNELS (FREQUENCY DIVERSITY) ARE PROVIDED ON PRACTICALLY ALL MICROWAVE SYSTEMS DESIGNED IN CANADA. IN CERTAIN CASES (OVERWATER PATH OR CERTAIN DIFFICULT REGIONS FROM AN ATMOSPHERIC POINT OF VIEW) SPACE DIVERSITY MIGHT BE REQUIRED TO ACHIEVE THE OBJECTIVE.

THE DEFINITION OF THE DIFFERENT TYPES OF DIVERSITY IS SHOWN ON PAGE 48. AS INDICATED ON PAGE 48, A SWITCH OR A COMBINER IS USED. THE MOST COMMON TYPES OF COMBINERS ARE: -

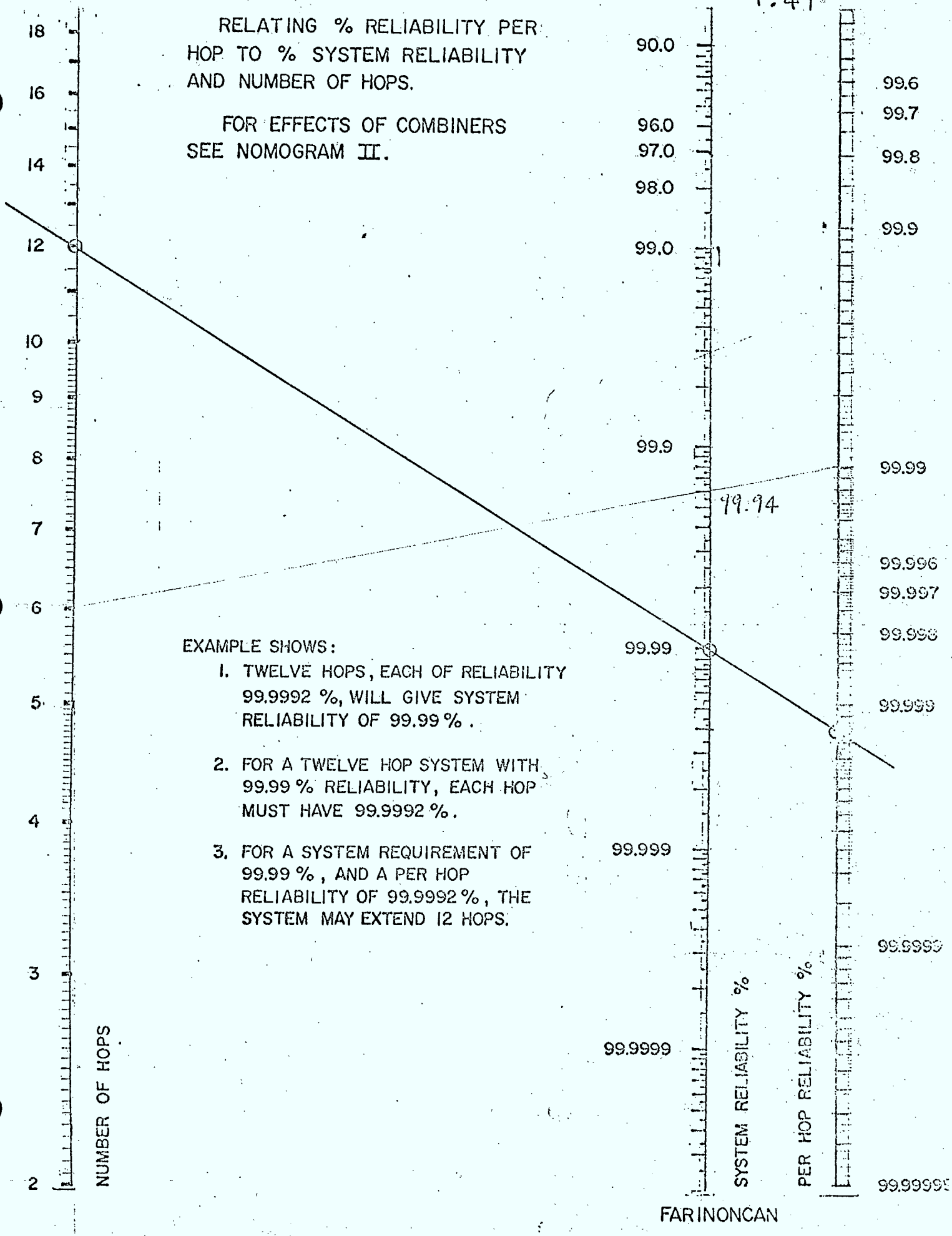
a) LINEAR ADDER COMBINERS

b) OPTIMAL RATIO COMBINERS

ADDITIONAL IMPROVEMENT IN THE TOTAL RELIABILITY COULD BE ACHIEVED BY COMBINING OR SWITCHING THE RECEIVED SIGNAL AFTER EACH HOP OR NUMBER OF HOPS (SEE PAGE 50).

RELATING % RELIABILITY PER HOP TO % SYSTEM RELIABILITY AND NUMBER OF HOPS.

FOR EFFECTS OF COMBINERS SEE NOMOGRAM II.

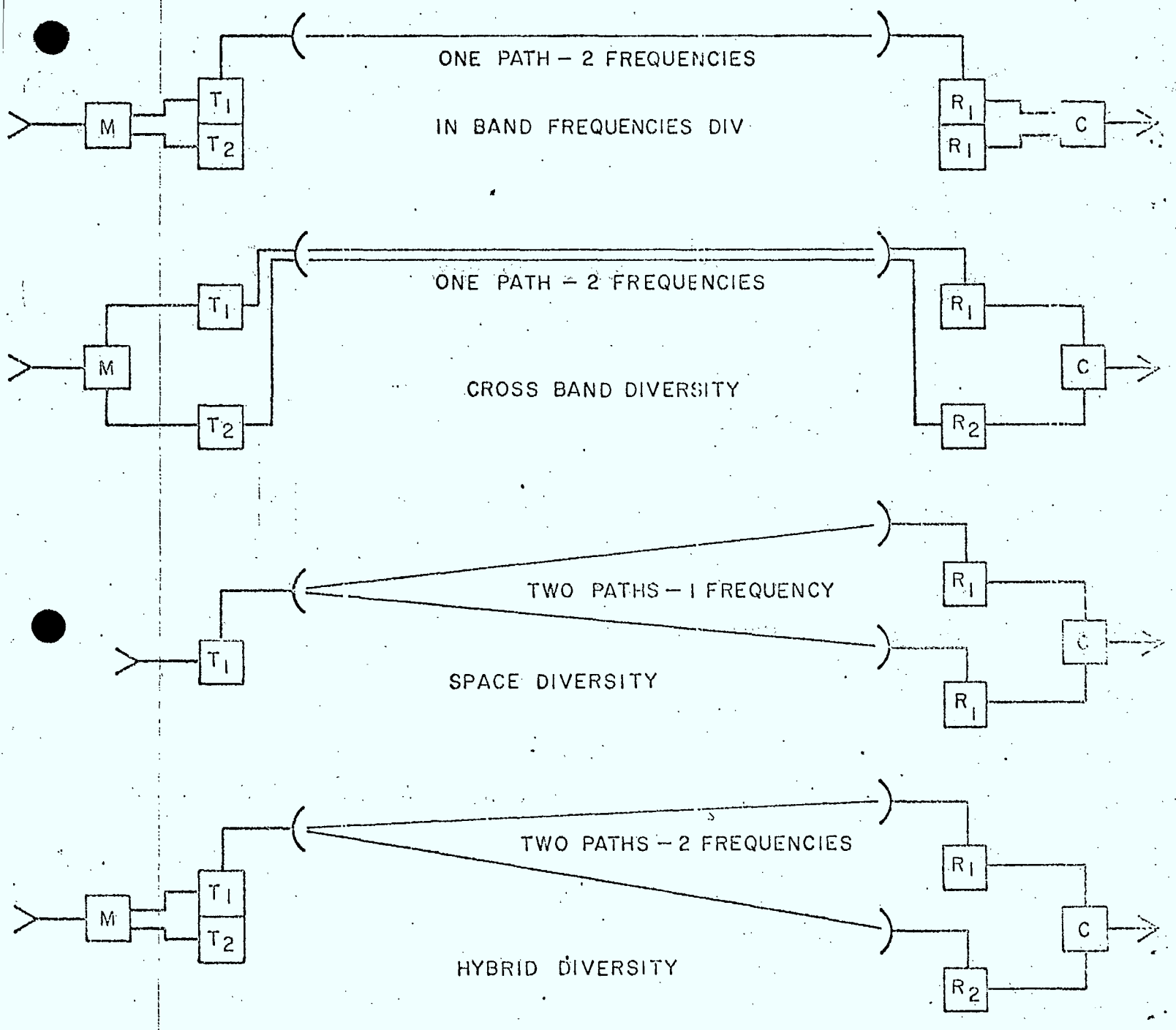


EXAMPLE SHOWS:

1. TWELVE HOPS, EACH OF RELIABILITY 99.9992 %, WILL GIVE SYSTEM RELIABILITY OF 99.99 % .
2. FOR A TWELVE HOP SYSTEM WITH 99.99 % RELIABILITY, EACH HOP MUST HAVE 99.9992 %.
3. FOR A SYSTEM REQUIREMENT OF 99.99 % , AND A PER HOP RELIABILITY OF 99.9992 %, THE SYSTEM MAY EXTEND 12 HOPS.

FARINONCAN

ON L-O-S PATHS
(ONE DIRECTION SHOWN)



T_1 = XMTR ON FREQUENCY 1

R_1 = RECR ON FREQUENCY 1

[C] = RECEIVER COMBINER OR SWITCH

[M] = TRANSMIT MULTIPLE FEED OR SWITCH

EXAMPLE: -

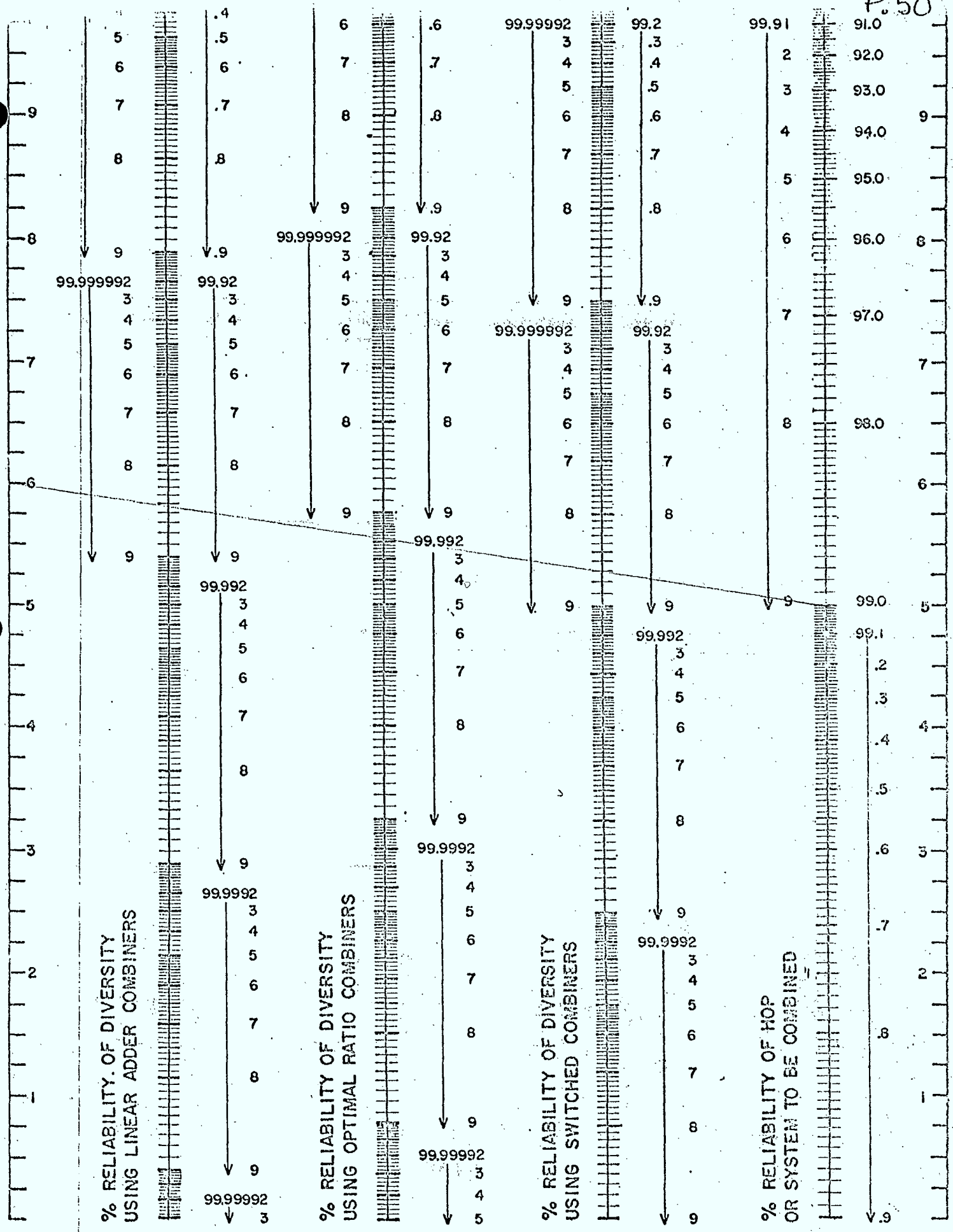
WHAT IS THE TOTAL RELIABILITY OF A SIX HOPS SYSTEM, WHERE EACH INDIVIDUAL HOP HAS A 99.99% RELIABILITY. FIND THE SAME IF THE SIGNAL IS COMBINED AFTER EACH HOP.

FROM PAGE 47, THE TOTAL RELIABILITY OF THE SYSTEM IS 99.94%.

FROM PAGE 50, THE TOTAL RELIABILITY OF THE SYSTEM IF THE SIGNAL IS COMBINED AT EACH HOP USING

a)	SWITCHED COMBINERS	99.9999987%
b)	OPTIMAL RATIO COMBINERS	99.9999992%
c)	LINEAR ADDER COMBINERS	99.9999985%

IT SHOULD BE NOTED THAT A RELIABILITY OF 99.99% MEANS THAT THE SYSTEM WILL HAVE OUTAGES TOTALING ONE HOUR DURING THE YEAR.


% RELIABILITY OF DIVERSITY
USING LINEAR ADDER COMBINERS
% RELIABILITY OF DIVERSITY
USING OPTIMAL RATIO COMBINERS
% RELIABILITY OF DIVERSITY
USING SWITCHED COMBINERS
% RELIABILITY OF HOP
OR SYSTEM TO BE COMBINED
FARINONCAN

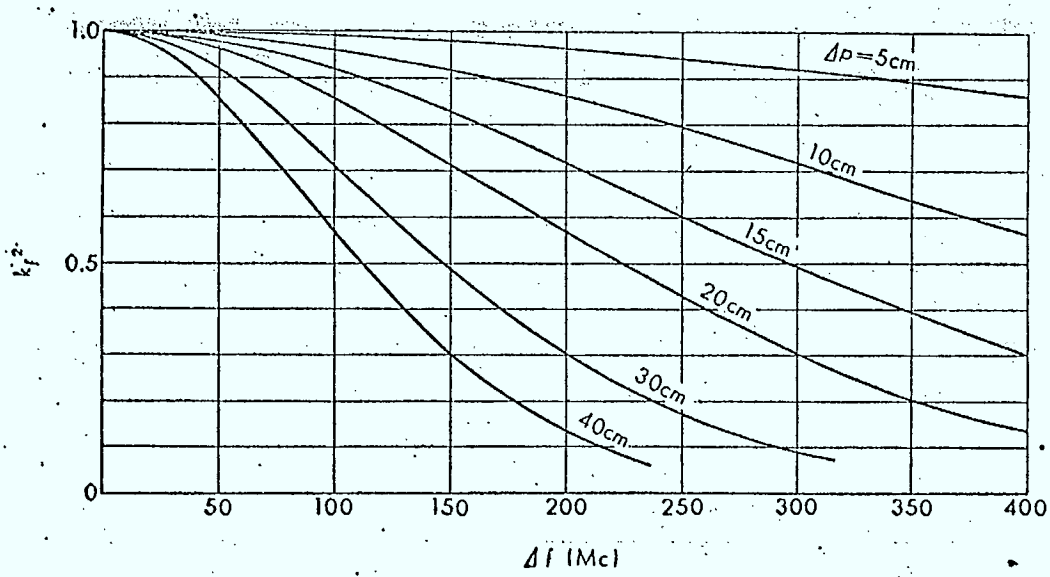
FREQUENCY DIVERSITY: -

MOST MICROWAVE SYSTEMS IN CANADA OPERATE ON A FREQUENCY DIVERSITY BASIS. THIS TYPE OF DIVERSITY IS USUALLY ACHIEVED BY ALLOCATING AN R.F. CHANNEL FOR A GROUP OF WORKING CHANNELS (USUALLY 3, 4, OR 5 WORKING CHANNELS) TO ACT AS A STAND BY PROTECTION.

FADING IS A USUALLY FREQUENCY SELECTIVE PROCESS. THIS MEANS THAT R.F. CHANNELS WILL FADE INDEPENDENTLY IF SEPARATED ENOUGH IN THE FREQUENCY SPECTRUM.

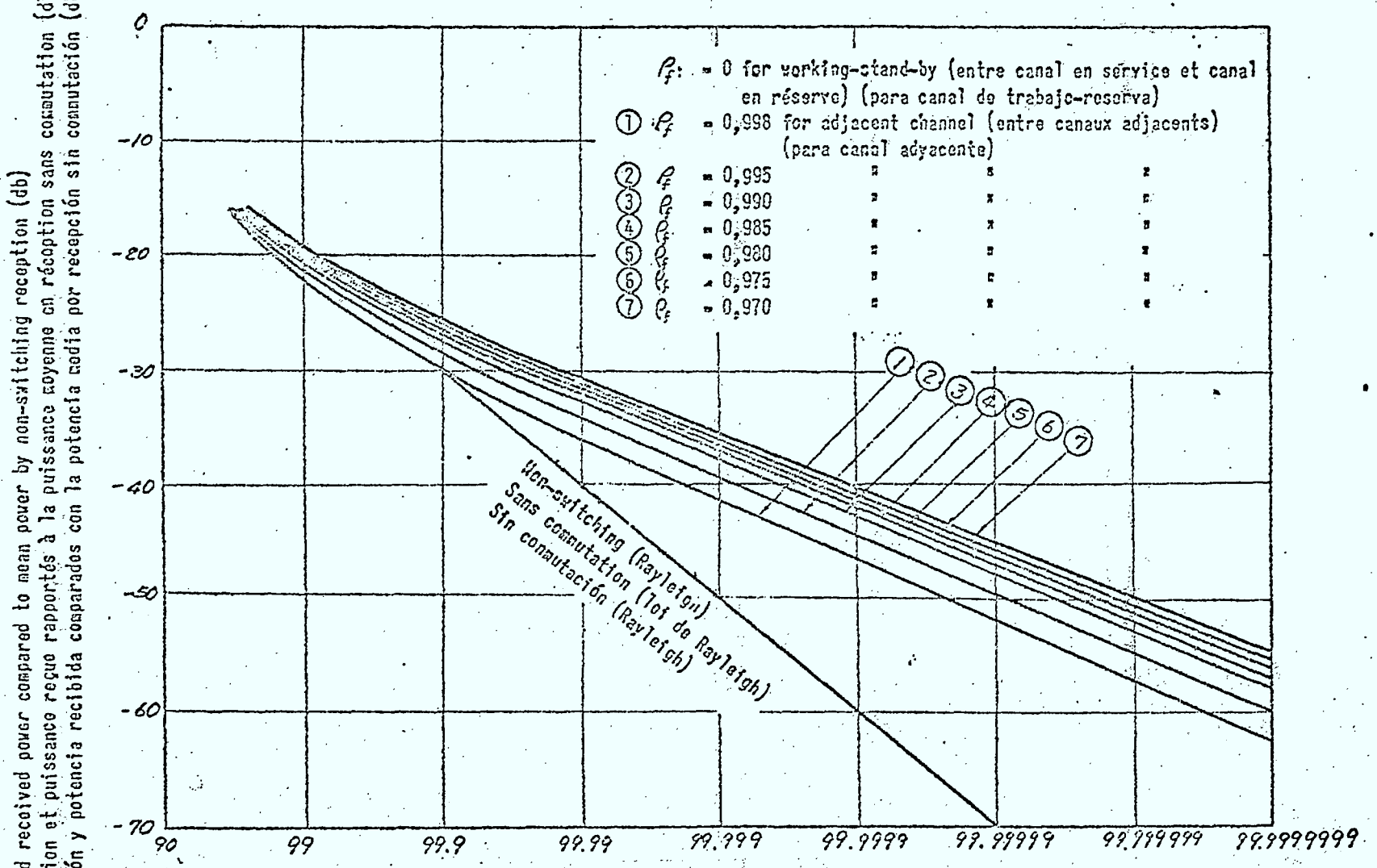
AT THIS TIME IT WILL BE USEFUL TO INTRODUCE THE "CORRELATION COEFFICIENT" CONCEPT. THIS COEFFICIENT VARIES IN VALUE BETWEEN 0 AND 1. IF TWO CHANNELS HAVE A CORRELATION COEFFICIENT 1 THAT MEANS THAT THEY ACT IN UNISON (THEY FADE TOGETHER). IT IS OBVIOUS THAT THE MAIN PURPOSE OF DIVERSITY IN THE PROPAGATION CONTEXT IS TO LOWER THE CORRELATION COEFFICIENT OF DIVERSE CHANNELS AS MUCH AS POSSIBLE IN ORDER THAT CHANNELS MIGHT FADE INDEPENDENTLY.

THE FIGURE BELOW SHOWS THE RELATIONSHIP OF THE FREQUENCY CORRELATION COEFFICIENT (k_f^2) AND THE FREQUENCY SEPARATION OF TWO CHANNELS. Δ P IS THE STANDARD DEVIATION OF PATH LENGTH DIFFERENCE DUE TO ATMOSPHERIC CONDITIONS.



—Frequency correlation coefficient k_f^2 of the received power.

THE GRAPH ON PAGE 53 IDENTIFIES THE CHANGE IN THE PROBABILITY OF FADE TO A CERTAIN POWER LEVEL BELOW F.S. LEVEL FOR DIFFERENT FREQUENCY CORRELATION COEFFICIENTS (k_f^2). THIS IS FOR AN ARRANGEMENT OF 4 WORKING CHANNELS AND A SINGLE PROTECTION CHANNEL.



CUMULATIVE DISTRIBUTION OF RECEIVED POWER FOR SWITCHING BETWEEN FOUR WORKING CHANNELS AND ONE STAND-BY CHANNEL

DISTRIBUTION CUMULATIVE DE LA PUISSANCE RECUE DANS LE CAS D'UNE COMMUTATION ENTRE QUATRE CANAUX EN SERVICE ET UN CANAL EN RESERVE

DISTRIBUCIÓN ACUMULATIVA DE LA POTENCIA RECIBIDA PARA LA CONMUTACIÓN ENTRE CUATRO CANALES DE TRABAJO Y UN CANAL DE RESERVA

SPACE DIVERSITY: -

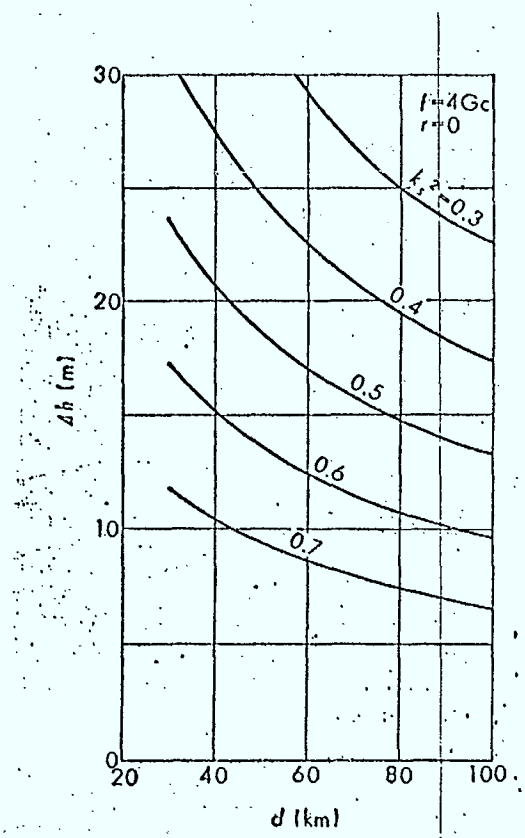
SPACE DIVERSITY IS USED TO IMPROVE THE RELIABILITY OF A MICROWAVE PATH IN THE FOLLOWING CONDITIONS: -

a) ATMOSPHERIC MULTIPATH FADING,

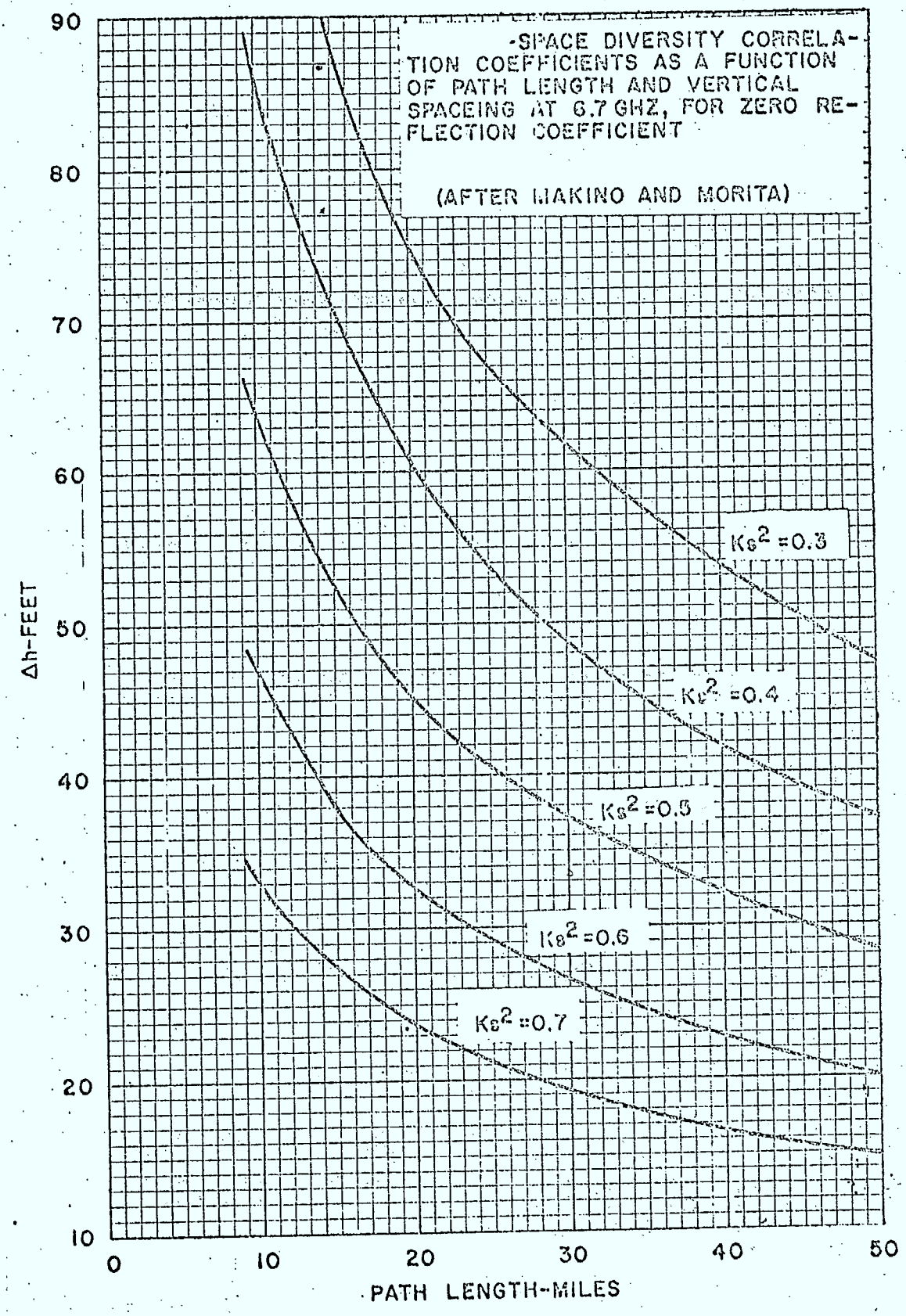
b) GROUND REFLECTED MULTIPATH FADING.

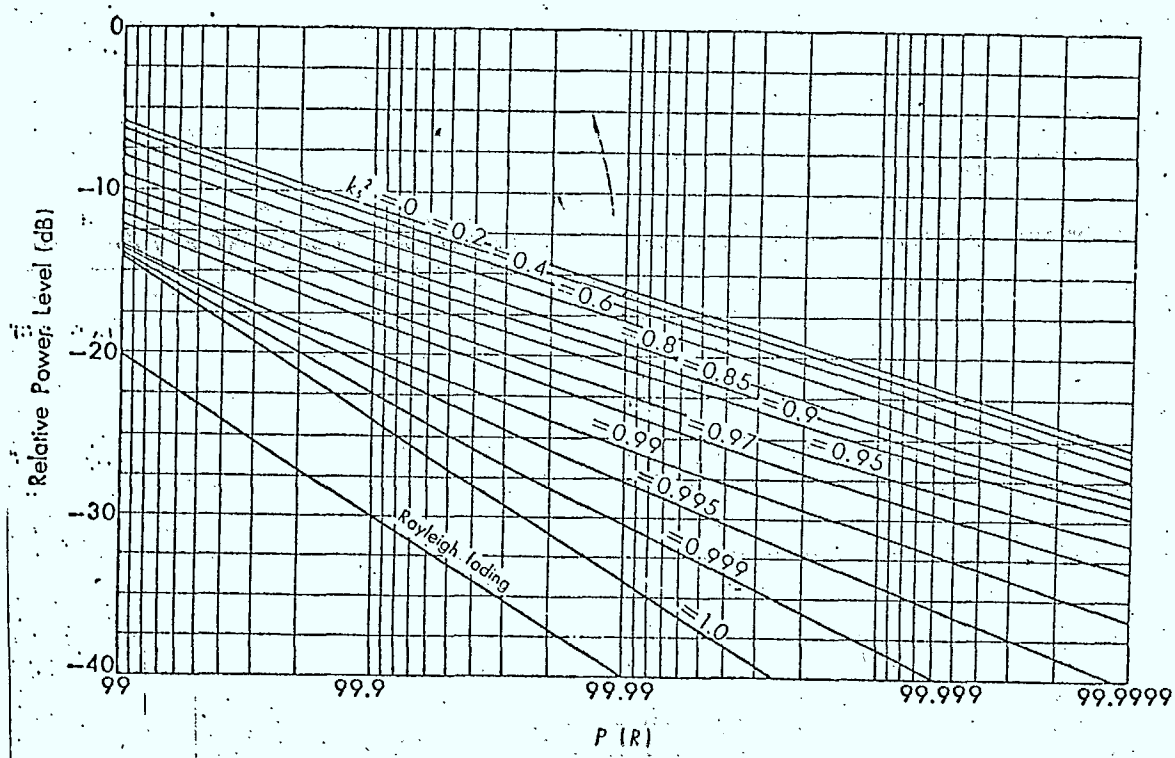
a) SPACE DIVERSITY FOR ATMOSPHERIC MULTIPATH: -

THE SPACE DIVERSITY CORRELATION COEFFICIENT (k_s^2) VARIES WITH THE PATH LENGTH, FREQUENCY, AND THE SEPARATION BETWEEN THE DIVERSE ANTENNAS.



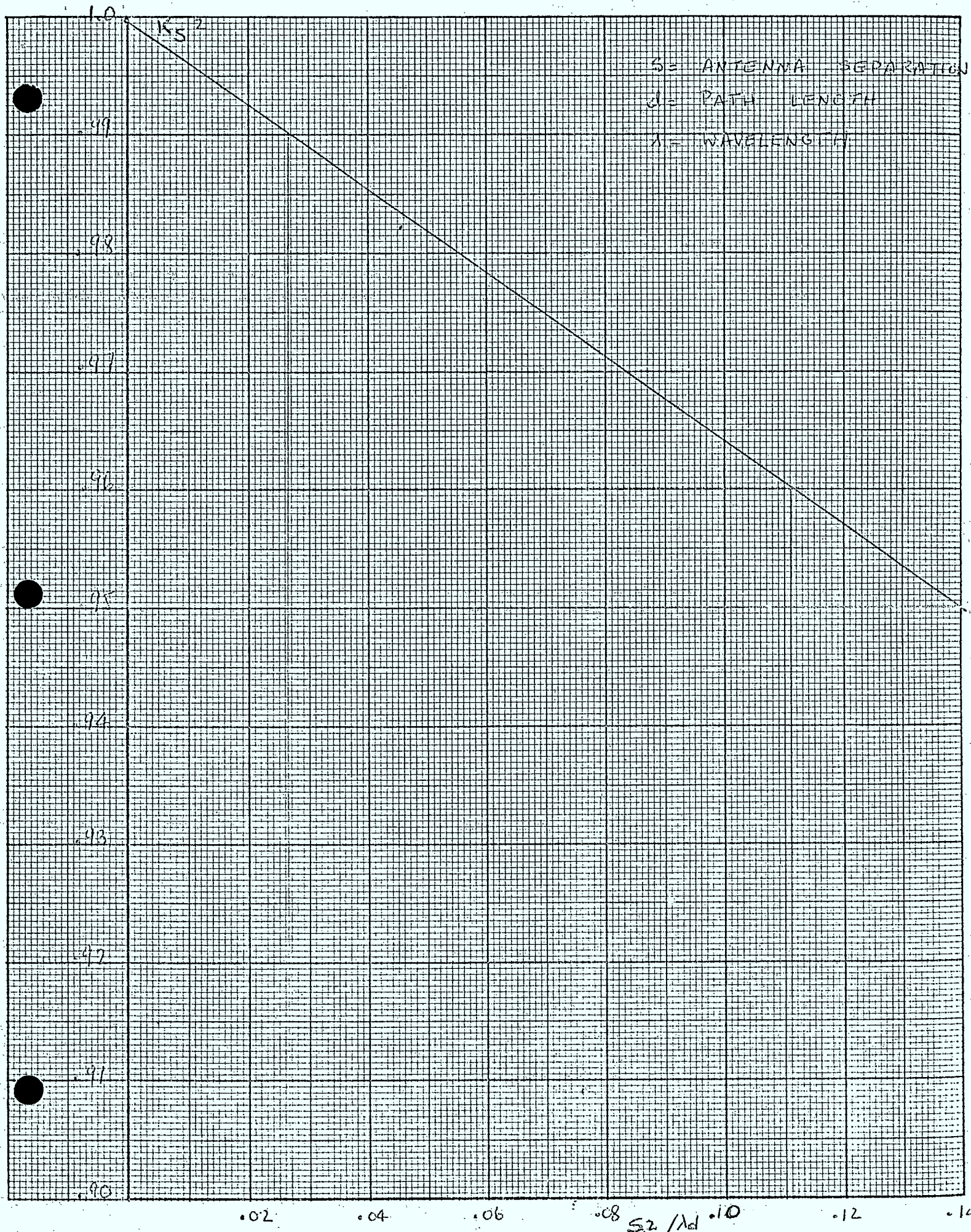
-Relations between the path length d and the vertical antenna separation Δh.


SPACE DIVERSITY CORRELATION COEFFICIENTS AS A FUNCTION OF PATH LENGTH AND VERTICAL SPACEING AT 6.7 GHZ, FOR ZERO REFLECTION COEFFICIENT
(AFTER MAKINO AND MORITA)
$K_s^2 = 0.3$
$K_s^2 = 0.4$
$K_s^2 = 0.5$
$K_s^2 = 0.6$
$K_s^2 = 0.7$
Δh-FEET
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
PATH LENGTH-MILES



—The cummulative probability $P(R)$ in %.

THE GRAPH ON THIS PAGE SHOWS THE IMPROVEMENT IN THE RELIABILITY OF A MICROWAVE PATH INDUCED BY THE LOWERING OF THE SPACE DIVERSITY CORRELATION COEFFICIENT.



335-5006 20 x 20

SIGNAL DIFFERENCE FROM NORMAL
PROBABILITY MAIN ANTENNA
FADE REDUCTION FACTOR
GAIN DIFFERENCE IN DB
S/√Nd
Fig. 2

PAGE 57 GIVES AN EMPIRICAL METHOD FOR DERIVING K_s^2.

EXAMPLE: -

A MICROWAVE PATH 26.5 MILES LONG OPERATING AT 4 GH_Z IS SUPPOSED TO ACHIEVE 99.99% RELIABILITY. AFTER PATH TESTING IT WAS DISCOVERED THAT THE RELIABILITY OF THE PATH IS ONLY 99% BECAUSE OF ATMOSPHERIC CONDITIONS. IF THE PATH DESIGN REQUIRES A 15' DISH WITH A GAIN OF 43DB AND THE TOWER CAN CARRY AN ADDITIONAL DISH NOT LARGER THAN 8' (GAIN 37DB). FIND THE ANTENNA SEPARATION REQUIRED TO IMPROVE THE RELIABILITY OF THE PATH.

THE ACTUAL OUTAGE RATE OF THE PATH 1%

THE REQUIRED OUTAGE RATE OF THE PATH .01%

AN IMPROVEMENT OF 100 TIMES IS REQUIRED.

THE DIFFERENCE IN THE GAINS OF THE ANTENNAS ARE 43 - 37 = 6DB.

FROM THE MONOGRAM ON PAGE 58 A K_s^2 OF .990 IS REQUIRED TO ACHIEVE IMPROVEMENT IN THE RELIABILITY. of similar antenna used, (15')

FROM PAGE 57 FOR $K_s^2 = .990 \rightarrow \frac{S^2}{D\lambda} = .027$

$$\frac{S}{\sqrt{D\lambda}} = \sqrt{.027} = .165$$

$$\frac{S^2}{D\lambda} = .027 \qquad D = 26.5 \times 5280 \text{ FEET}$$

$$\lambda = .25 \text{ FEET}$$

$$\frac{S^2}{26.5 \times 5280 \times .25} = .027$$

$$S^2 = 945 \text{ SQUARE FEET}$$

$$S = 30.7 \text{ FEET}$$

A SEPARATION OF 30.7 FEET IS REQUIRED FOR A DIVERSITY ACHIEVED WITH TWO 15' DISHES.

FOR AN 8' DISH $K_s^2 = .960$ & $\frac{S^2}{D\lambda} = .111$

$$\frac{S^2}{26.5 \times 5280 \times .25} = .111$$

$$S^2 = 3890$$

$$S = 62.4 \text{ FEET}$$

b) SPACE DIVERSITY FOR TERRAIN REFLECTION

WHEN FADING OCCURS BECAUSE OF A LOCALIZED REFLECTION ON THE PATH TERRAIN, SPACE DIVERSITY COULD BE USED SUCCESSFULLY TO IMPROVE THE RELIABILITY OF THE PATH.

THE DIVERSITY IS ACHIEVED BY SEPARATING THE TWO RECEIVING ANTENNAS IN SUCH A MANNER THAT WHEN ONE OF THEM IS FADING THROUGH AN EVEN FRESNEL ZONE THE OTHER ANTENNA IS GAINING THROUGH AN ODD ZONE.

EXAMPLE: -

FOR THE PATH SHOWN ON PAGE 62 CALCULATE THE SEPARATION REQUIRED TO ACHIEVE SPACE DIVERSITY.

$$F_1 = 36\sqrt{\frac{d_1\, d_2}{D}} \qquad \text{(FOR 4 GH}_Z\text{)}$$

FOR K = ∞ $\qquad d_1 = 5.86$ MILES

$d_2 = 11.14$ MILES

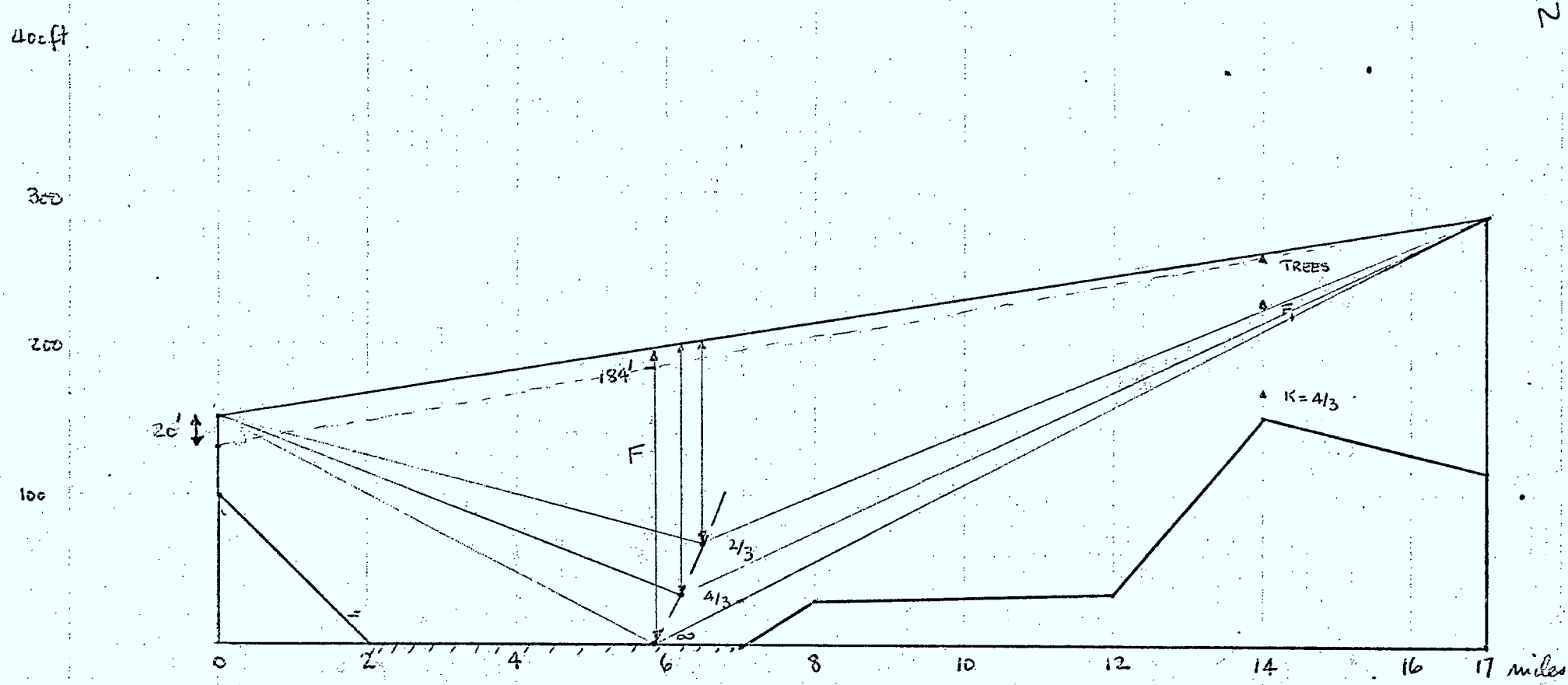
D = 17 MILES

F_1 = 70.5 FEET AND F = 197 FEET

$$\left(\frac{F}{F_1}\right)^2 = m$$

$$\left(\frac{197}{70.5}\right)^2 = m = 7.8$$

AT	$K = \infty$	F = 197 ft	d_1 = 5.86 miles
	$K = 4/3$	F = 166 ft.	d_1 = 6.2 miles
	$K = 2/3$	F = 130 ft.	d_1 = 6.5 miles



TO ACHIEVE THE DIVERSITY NEEDED THE FRESNEL ZONE OF THE SECOND ANTENNA SHOULD BE EITHER 8.8 OR 6.8. USUALLY THE SECOND ANTENNA IS BELOW THE ORIGINAL ONE.

$$\text{FOR } \mathfrak{M} = 6.8 = \left(\frac{F}{F_1}\right)^2$$

F_1 IS APPROXIMATELY 70.5 FEET

$$F = F_1\sqrt{6.8} = 184 \text{ FEET}$$

FROM THE PATH ON PAGE 62, THE SEPARATION OF THE ANTENNAS IS APPROXIMATELY 20 FEET.

WE OPTIMIZE THE ANTENNA SEPARATION AT K = INFINITY BECAUSE THE WORST REFLECTION OCCURS AT THIS CONDITION SINCE THE DIVERGENCE FACTOR WILL EQUAL 1.

SPACE DIVERSITY VERSUS FREQUENCY DIVERSITY (BY R. F. WHITE)

ALTHOUGH EITHER FORM OF DIVERSITY CAN PROVIDE GOOD IMPROVEMENT AGAINST MULTIPATH FADING, THERE ARE SEVERAL THINGS WHICH MAKE THE FREQUENCY DIVERSITY APPROACH ATTRACTIVE. ONE, OF COURSE, IS THAT IT REQUIRES ONLY A SINGLE ANTENNA AND WAVEGUIDE SYSTEM WHEREAS A SPACE DIVERSITY REQUIRES TWO COMPLETE SETS. FURTHERMORE THE SPACE DIVERSITY ARRANGEMENT IMPOSES A HEAVIER LOADING REQUIREMENT ON THE TOWERS AND MAY, DEPENDING ON THE CLEARANCE CRITERIA CHOSEN, EVEN REQUIRE THAT THE TOWERS BE HIGHER THAN FOR FREQUENCY DIVERSITY. A 1 FOR 1 FREQUENCY DIVERSITY SYSTEM AUTOMATICALLY GIVES 100% EQUIPMENT REDUNDANCY, WITH NO REQUIREMENT FOR DOING ANY SWITCHING AT THE TRANSMIT END. A POSTDETECTION SPACE DIVERSITY SYSTEM GIVES RECEIVER STANDBY, BUT IN ORDER TO GET TRANSMITTER REDUNDANCY IT IS NECESSARY TO

PROVIDE A DUPLICATE TRANSMITTER WITH AUTOMATIC SWITCHING AND TRANSFER EQUIPMENT: IN ADDITION TO BEING MORE COMPLEX AND COSTLY THAN THE SIMPLE TRANSMITTER ARRANGEMENT USED IN A FREQUENCY DIVERSITY SYSTEM, THE SWITCHING AND TRANSFER EQUIPMENT ALSO INTRODUCES AN ADDITIONAL POTENTIAL SOURCE OF TROUBLE.

A POINT OF VERY GREAT IMPORTANCE IN THE COMPARISON, PERHAPS NOT FULLY REALIZED EXCEPT BY THE PEOPLE WHO HAVE TO OPERATE AND MAINTAIN A SYSTEM, IS THAT A FREQUENCY DIVERSITY SYSTEM ALLOWS COMPLETE END TO END TESTING, LINE-UP AND MAINTENANCE TO BE DONE OVER A PATH WITHOUT ANY INTERRUPTION AT ALL TO SERVICE. THIS IS POSSIBLE, OF COURSE, BECAUSE IN A FREQUENCY DIVERSITY SYSTEM THERE ARE TWO COMPLETELY SEPARATE END TO END ELECTRICAL PATHS, EITHER ONE OF WHICH CAN CARRY THE SERVICE WHILE THE OTHER IS BEING MAINTAINED. THE SPACE DIVERSITY SYSTEM, THOUGH IT HAS TWO END TO END PHYSICAL PATHS THROUGH THE ATMOSPHERE, HAS ONLY ONE COMPLETE ELECTRICAL PATH. IN ORDER TO DO FULL END TO END TESTING IT IS NECESSARY TO INTERRUPT THE SERVICE. IN THE TYPE OF 24-HOUR A DAY OPERATION TYPICAL OF MOST HIGH DENSITY MULTI-CHANNEL SYSTEMS THIS IS A DIFFICULT THING TO DO WITHOUT UNDESIRABLE REPERCUSSIONS.

ANOTHER DRAWBACK OF SPACE DIVERSITY IS THAT IT DOES NOT ALLOW THE USE OF ONE PROTECTION CHANNEL AS A STANDBY FOR TWO OR MORE WORKING CHANNELS. FREQUENCY DIVERSITY, ON THE OTHER HAND, CAN BE EXPANDED BY A SWITCHING ARRANGEMENT TO ALLOW ONE PROTECTION CHANNEL TO PROVIDE BOTH EQUIPMENT PROTECTION AND A CONSIDERABLE DEGREE OF DIVERSITY PROTECTION FOR AS MANY AS FOUR OR FIVE WORKING CHANNELS. SUCH SYSTEMS HAVE BEEN IN WIDESPREAD USE IN THE COMMUNICATIONS INDUSTRY FOR MANY YEARS AND THEIR CHARACTERISTICS ARE WELL KNOWN.

WHEN USED IN A SIMPLE 1 FOR 1 ARRANGEMENT, WHERE ONLY A SINGLE WORKING CHANNEL IS REQUIRED, FREQUENCY DIVERSITY OF COURSE REQUIRES TWICE AS MUCH FREQUENCY SPECTRUM AS THE EQUIVALENT SPACE DIVERSITY SYSTEM. THIS IS THE PRINCIPAL DISADVANTAGE OF FREQUENCY DIVERSITY, AND IT IS ONE WHICH BECOMES INCREASINGLY IMPORTANT AS FREQUENCY CONGESTION INCREASES.

A QUESTION OF CONSIDERABLE INTEREST IS THE RELATIVE MERIT OF FREQUENCY DIVERSITY AND SPACE DIVERSITY, CONSIDERED STRICTLY FROM THE STANDPOINT OF PROPAGATION PROTECTION. THERE ARE CONFLICTING VIEWS ON THE MATTER. HISTORICALLY IT APPEARS THAT THE PREVAILING VIEW HAS BEEN THAT VERTICAL SPACE DIVERSITY IS MOST EFFECTIVE AGAINST GROUND OR WATER REFLECTED MULTIPATH AND FREQUENCY DIVERSITY THE MOST EFFECTIVE AGAINST ATMOSPHERIC MULTIPATH. THOUGH WE HAVE LITTLE OR NO DIRECT COMPARATIVE EVIDENCE, OUR OWN EXPERIENCES HAVE LED TO THE CONCLUSION THAT VERTICAL SPACE DIVERSITY IS CERTAINLY AS EFFECTIVE AS FREQUENCY DIVERSITY REGARDLESS OF THE SOURCE OF THE MULTIPATH, AND IN SOME CASES IS ALMOST CERTAINLY SUPERIOR.

IN THIS CONNECTION, A POINT OF CONSIDERABLE IMPORTANCE IS THAT IN FREQUENCY DIVERSITY SYSTEMS THERE IS USUALLY, BECAUSE OF ASSIGNED BANDS AND ALLOCATIONS, A LIMIT ON THE AMOUNT OF FREQUENCY SPACING WHICH CAN BE USED. FOR EXAMPLE, 2% SPACING IS QUITE WIDELY USED EVEN THOUGH IT IS OFTEN CONSIDERED THAT 5% SPACING IS NEEDED TO PROVIDE ESSENTIALLY UNCORRELATED FADING. ON THE OTHER HAND, WITH SPACE DIVERSITY SYSTEMS THERE IS NO BASIC LIMIT OTHER THAN COST TO THE SPACING WHICH CAN BE USED. THUS THERE IS WITH SPACE DIVERSITY MORE FLEXIBILITY IN CHOOSING A LARGE ENOUGH SPACING, OR EVEN AN OPTIMUM SPACING, IF INDEED AN OPTIMUM EXISTS. IT IS ALSO RELATIVELY EASY WITH SPACE DIVERSITY TO CHANGE OR EVEN EXPERIMENT WITH THE

SPACING IN THE FIELD, BUT THIS IS USUALLY A VERY DIFFICULT THING TO DO WITH FREQUENCY DIVERSITY.

A STUDY OF SOME OF THE FADING CHARTS TAKEN ON SPACE DIVERSITY SYSTEMS INDICATES THAT THERE MAY BE ANOTHER ADVANTAGE TO SPACE DIVERSITY. MANY OF THE LONG SLOW FADES OF THE TYPE WHICH USUALLY EXHIBIT LITTLE OR NO FREQUENCY SELECTIVE EFFECT, DO SEEM TO HAVE A CONSIDERABLE AMOUNT OF SPACE SELECTIVITY. THIS MIGHT BE EXPLAINED UNDER THE ASSUMPTION THAT THE MECHANISM PRODUCING THE VARIATIONS, WHETHER DEFOCUSSING OR SOME OTHER PHENOMEMON, MIGHT BE PRESENT ON THE UPPER OR THE LOWER PATH WHILE ABSENT OR PARTIALLY ABSENT ON THE OTHER. FREQUENCY DIVERSITY, OF COURSE, HAS ONLY ONE PHYSICAL PATH.

MUCH MORE EVIDENCE IS NEEDED BEFORE ANY DEFINITIVE CONCLUSIONS CAN BE REACHED ON THE MATTER OF RELATIVE MERITS OF THE TWO METHODS. CAREFULLY CONTROLLED SIMULTANEOUS TESTING OVER LONG PERIODS OF TIME, UNDER VARIED CONDITIONS, AND OVER PATHS WITH DIFFERING CHARACTERISTICS WOULD BE VERY DESIRABLE, BUT SUCH FULL SCALE TESTING CAN BECOME SO COMPLEX AND EXPENSIVE AS TO BE BEYOND THE CAPACITIES OF ALL BUT THE LARGEST COMMUNICATIONS ORGANIZATIONS.

THE GRAPH ON PAGE 68 RELATES RELIABILITY TO THE OUTAGE TIME PER YEAR. FOR EXAMPLE A SYSTEM WITH A RELIABILITY OF 99.98% WILL HAVE A TOTAL CUMULATIVE OUTAGE OF 110 MINUTES PER YEAR. A SYSTEM WITH A RELIABILITY OF 99.998% WILL HAVE A TOTAL CUMULATIVE OUTAGE OF APPROXIMATELY 10 MINUTES PER YEAR.

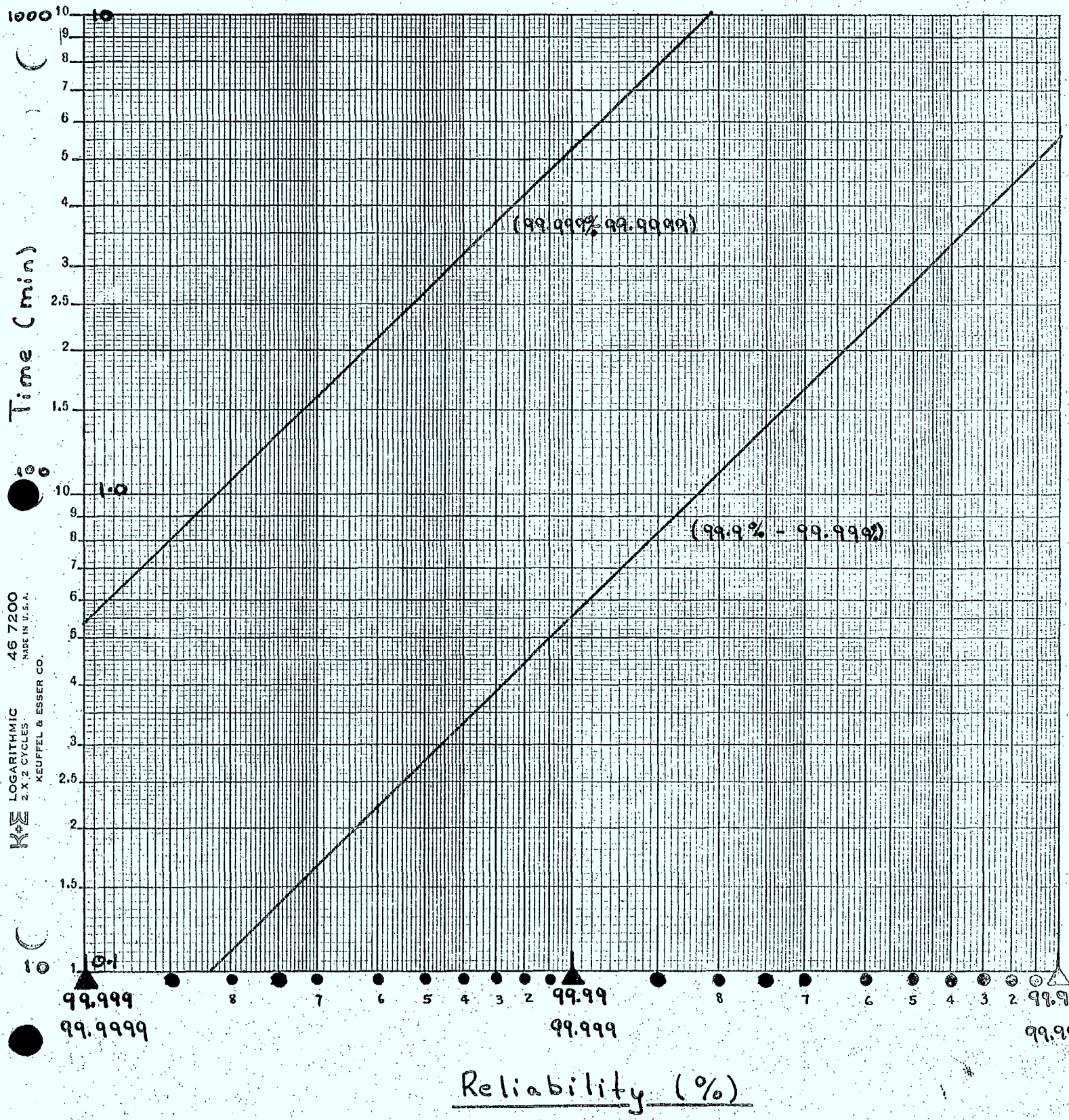
FREQUENCY DIVERSITY SWITCHING EQUIPMENT: -

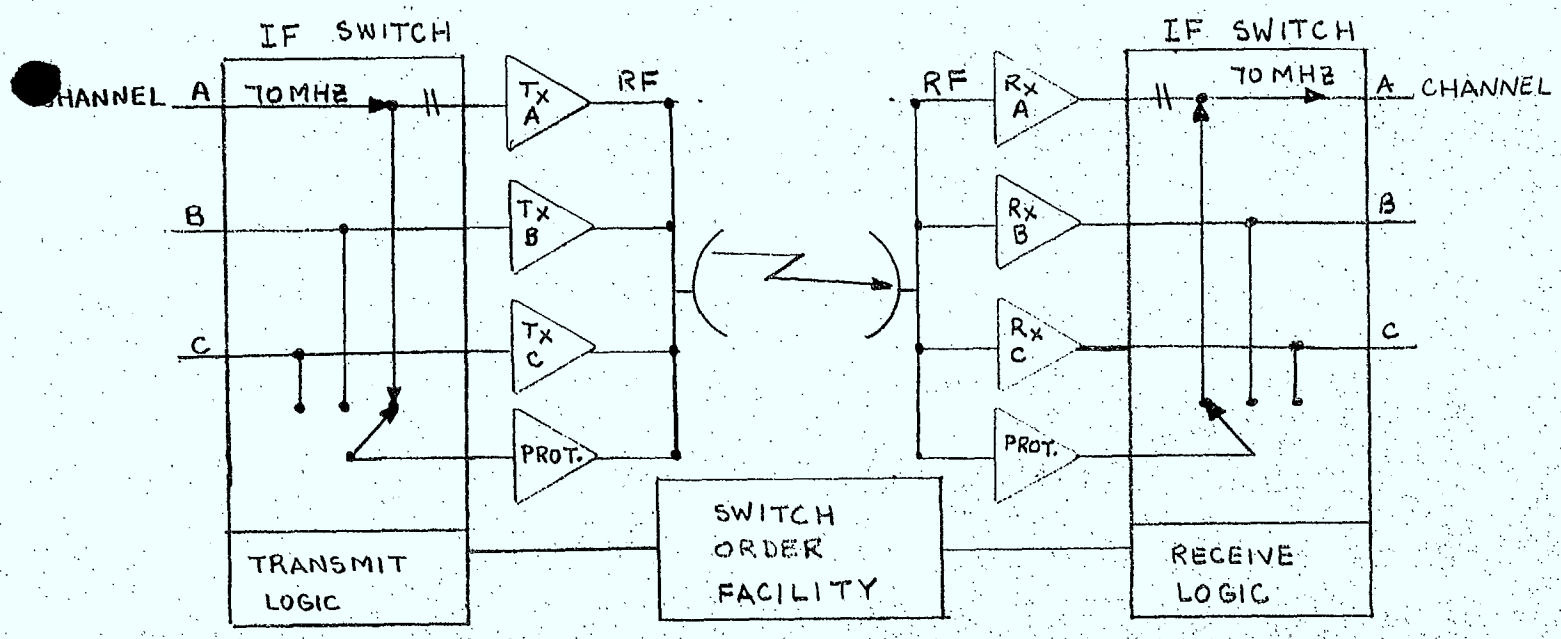
AS DISCUSSED IN THE PROPAGATION SECTION OF THIS COURSE FREQUENCY DIVERSITY IMPROVES THE RELIABILITY OF A MICROWAVE SYSTEM. MOST MICROWAVE SYSTEMS OPERATE ON A FREQUENCY DIVERSITY BASIS IN THE FORM OF A PROTECTION CHANNEL FOR 3, 4, 5 . . . . . WORKING CHANNELS. THE TOP FIGURE ON PAGE 69 SHOWS A ONE HOP IF SWITCHING SECTION. THE AVERAGE NUMBER OF HOPS IN A SWITCHING SECTION IS APPROXIMATELY 6 FOR NORTH AMERICAN MICROWAVE SYSTEMS.

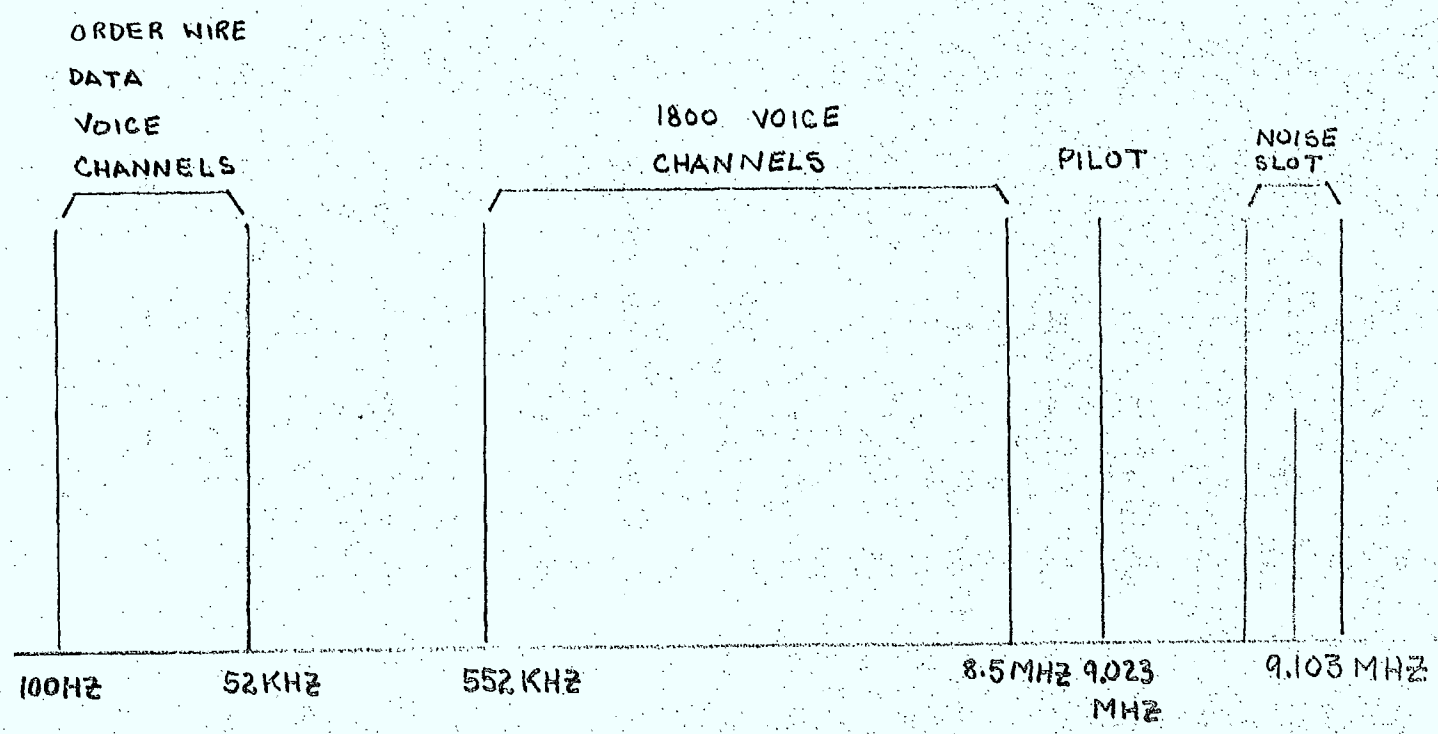
IT IS WORTH NOTING THAT THERE ARE THREE FUNDAMENTAL FREQUENCIES IN THE MICROWAVE EQUIPMENT.

- BASEBAND FREQUENCIES (b/b) - SEE LOWER FIGURE ON PAGE 69
- INTERMEDIATE FREQUENCIES (IF) - CENTERED AROUND THE 70 MH_Z FREQUENCY
- RADIO FREQUENCIES (RF) - THE FREQUENCIES PROPAGATED FROM ONE ANTENNA TO ANOTHER.

Outage Time Per Year vs. Reliability




IF SWITCH
CHANNEL A
70MHZ
B
C
TX A
TX B
TX C
PROT.
RF
TRANSMIT LOGIC
SWITCH ORDER FACILITY
RF
RX A
RX B
RX C
PROT.
IF SWITCH
70 MHZ
A CHANNEL
B
C
RECEIVE LOGIC


ORDER WIRE
DATA
VOICE CHANNELS
1800 VOICE CHANNELS
PILOT
NOISE SLOT
100HZ
52KHZ
552 KHZ
8.5MHZ
9.023 MHZ
9.103 MHZ
FREQUENCY

IN THE SWITCHING DIAGRAM ON PAGE 69, CHANNEL A IS IN THE FAILED CONDITION. THE SWITCHING EQUIPMENT DETECTED THE EXCESSIVE NOISE IN CHANNEL A BY MONITORING ITS NOISE SLOT CENTERED AROUND 9.103 MH_Z AND A FEW KH_Z WIDE. THE PILOT AT 9.023 MH_Z IS A COMMUNITY PILOT. AT THIS POINT IN TIME, THE RECEIVE LOGIC INITIATED THE SWITCHING SEQUENCE, AND VIA THE SWITCH ORDER FACILITY, NOTIFIED THE TRANSMIT LOGIC TO BRIDGE THE TRAFFIC OF THE FAILED CHANNEL TO THE PROTECTION CHANNEL. THE SWITCH ORDER FACILITY CARRIES INFORMATION FROM THE RECEIVE LOGIC TO THE TRANSMIT LOGIC, EITHER BY TRANSMITTING THE COMMAND INFORMATION OF THE RECEIVE LOGIC TO THE TRANSMIT LOGIC USING AN UNUSED PORTION OF FREQUENCY SPECTRUM OF ONE OR TWO RADIO CHANNELS GOING IN THE OPPOSITE DIRECTION, OR BY EXTERNAL ORDER WIRE RADIO OR CABLE FACILITIES.

IF THE PROTECTION CHANNEL IS AVAILABLE, OR IF THE FAILED CHANNEL IS A PRIORITY CHANNEL, THE TRANSMIT LOGIC BRIDGED THE TRAFFIC OF CHANNEL A TO THE PROTECTION CHANNEL WHICH THEN RELAYED THE INFORMATION TO THE RECEIVE END, COMPLETING THE BRIDGING. THE INTERRUPT TIME OF CHANNEL A, WHILE BEING SWITCHED IS A FEW MICROSECONDS, DEPENDING ON THE NUMBER OF HOPS IN THE SWITCHING SECTION. THE EFFECT OF THIS INTERRUPTION WILL DEPEND ON THE TYPE OF INFORMATION BEING TRANSMITTED ON THE FAILING CHANNEL.

TYPE OF TRAFFIC	MAXIMUM TOLERABLE INTERRUPT TIME	EFFECT IF TOLERANCE IS EXCEEDED
VIDEO	$<$ 100 MICROSECONDS	LOSS OF SYNCHRONIZATION ROLLING
TELEGRAPH (50 BAND)	$<$ 1 MILLISECOND	ERROR
DATA	$<$ 10 MICROSECONDS	ERROR
MESSAGE CIRCUITS	$<$ 100 MILLISECONDS	SEIZURE OF CENTRAL OFFICE SWITCHING EQUIPMENT.

OTHER CONSIDERATIONS WHEN DESIGNING MICROWAVE SYSTEMS: -

THERE ARE MANY OTHER CONSIDERATIONS THAT INFLUENECE THE SITE SELECTION PROCESS WHEN A MICROWAVE SYSTEM IS BEING PLANNED.

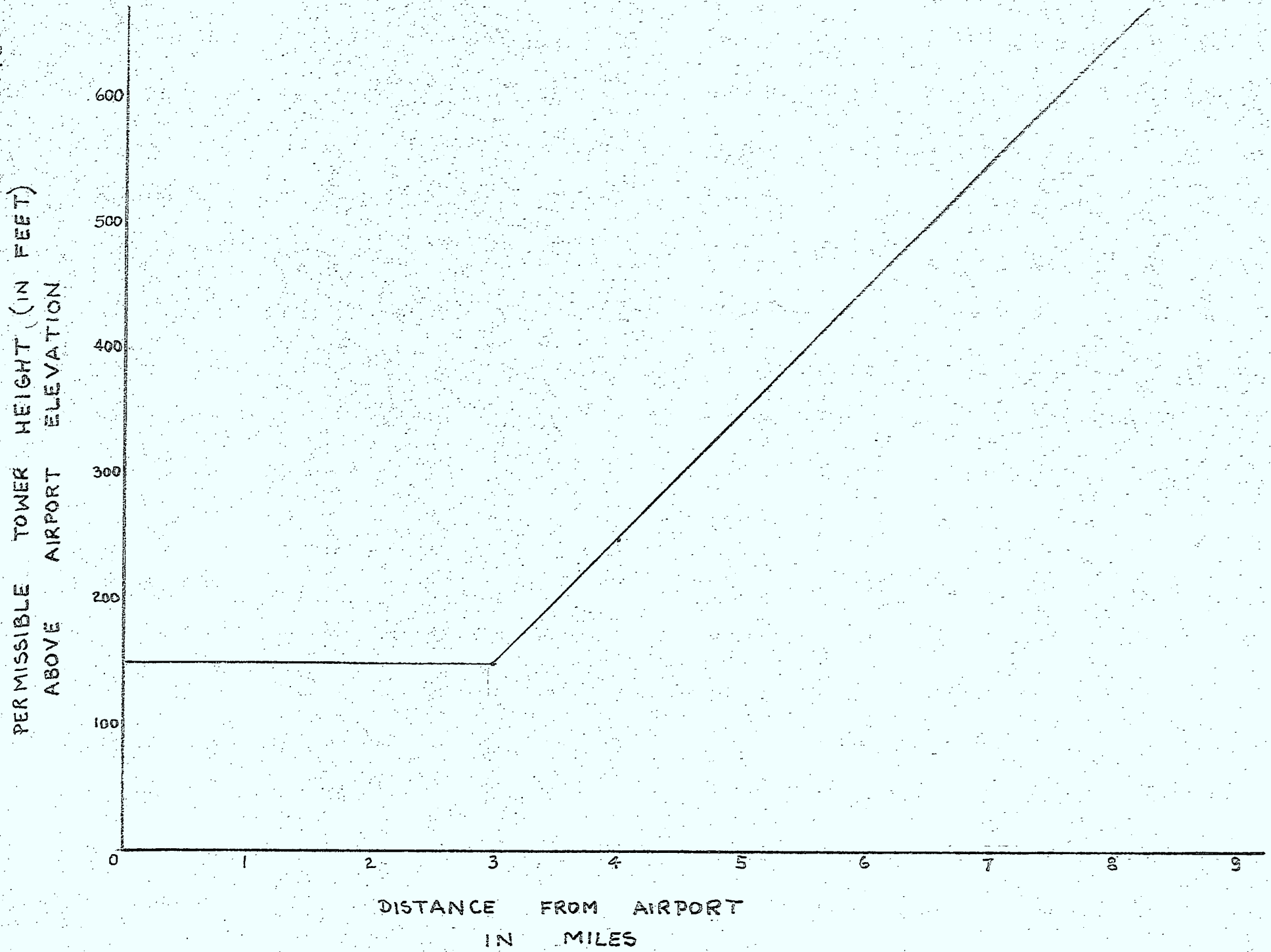
a) TO MINIMIZE THE COST OF ACCESS ROADS TO A MICROWAVE SITE AND ITS MAINTENANCE, IT IS OBVIOUS THAT THE IDEAL SITE WOULD BE THE ONE LOCATED CLOSE TO HIGHWAYS OR ROADS WHICH ARE WELL MAINTAINED SPECIALLY IN WINTER.

b) IT IS IMPORTANT TO CHOOSE THE MICROWAVE SITE IN AN AREA SERVED BY COMMERCIAL POWER DISTRIBUTION LINES. IF NOT, THIS WILL MEAN THAT MAIN AND BACK-UP DIESEL GENERATORS HAVE TO BE INSTALLED ON SITE WITH FREQUENT REFUELLING TRIPS REQUIRED FROM THE PERSONNEL .

c) IF THERE ARE REQUIREMENTS TO BUILD A MICROWAVE SITE IN AN URBAN AREA, THIS SHOULD BE DONE IN SUCH A MANNER AS TO COMPLY WITH ZONING REGULATIONS.

d) WHEN BUILDING MICROWAVE TOWERS LESS THAN 3 MILES FROM AN AIRPORT, THE TOWER STRUCTURE SHOULD NOT BE IN DIRECT LINE WITH THE AIRPORT RUNWAYS AND, LIGHTED AND PAINTED PROPERLY TO CONFORM WITH DOT REGULATIONS. THE GRAPH ON PAGE 73 SHOWS THE TOWER HEIGHT REGULATION FOR A TOWER STRUCTURE NOT IN DIRECT LINE WITH THE AIRPORT RUNWAYS, AND MEETING THE PAINTING AND LIGHTING REQUIREMENT SET BY DOT.

e) DOT PUBLISHES MAPS OF CANADA INDICATING THE CENTER LINES OF AIRWAYS AND THE MINIMUM FLYING LEVEL IN FEET IN THESE AIRWAYS. A TOWER STRUCTURE SHOULD BE MORE THAN A 1000 FEET BELOW THE MINIMUM FLYING LEVEL, FIVE MILES ON EACH SIDE OF THE AIRWAY CENTER LINE.


PERMISSIBLE TOWER HEIGHT (IN FEET)
ABOVE AIRPORT ELEVATION
600
500
400
300
200
100
0
1
2
3
4
5
6
7
8
9
DISTANCE FROM AIRPORT
IN MILES

STANDARD RADIO SYSTEM PLANS (SRSP)

THESE DOCUMENTS ARE AVAILABLE FROM DOC. THESE DOCUMENTS INDICATE THE PROPER USAGE OF THE FREQUENCY SPECTRUM. THE FOLLOWING IS A NUMBERICAL LIST OF SRSPs.

NO.	TITLE
300	TECHNICAL REQUIREMENTS FOR INSTRUCTIONAL TELEVISION FIXED STATIONS OPERATING IN THE 2548 TO 2686 MH_Z BAND.
301	TECHNICAL REQUIREMENTS FOR L.O.S. RADIO RELAY SYSTEMS (5925-6425 MH_Z)
302	" " " " " " " (3500-4200 MH_Z)
303	" " " " " " " (1710-1900 MH_Z)
304	" " " " " " " (1900-2290 MH_Z)
305	" " " " " " " (7125-7725 MH_Z)
306	" " " " " " " (7725-8275 MH_Z)
307	" " " " " " " (6425-6590 MH_Z) (6770-6930 MH_Z)
308	" " " RADIO RELAY SYSTEMS PROVIDING TV.

AUXILIARY SERVICES IN THE BANDS 6590-6770 MH_Z AND 6930-7125 MH_Z.

2548-2686 MH_Z

THIS BAND IS ALLOCATED TO INSTRUCTIONAL T.V. FIXED STATION. TO ALLOW THE ORDERLY GROWTH OF THIS SERVICE, THE AREAS OF CANADA THAT ARE RELATIVELY HEAVILY POPULATED HAVE BEEN DIVIDED INTO A NUMBER OF ZONES WITH THE CENTER OF EACH ZONE COINCIDENT WITH THE PROBABLE ITV DISTRIBUTION CENTERS. THE RADIUS OF MOST ZONES IS 30 MILES WHICH IS THE OUTER LIMIT OF THE COVERAGE AREA FOR THESE ZONES. THESE ZONES ARE IDENTIFIED ON PAGES 77 AND 78.

IT SHOULD BE NOTED THAT WHEN LOW DIRECTIONAL ANTENNAS ARE USED, THE MAXIMUM ALLOWABLE DISTANCE BETWEEN TRANSMITTERS AND RECEIVERS SHOULD NOT EXCEED 30 MILES.

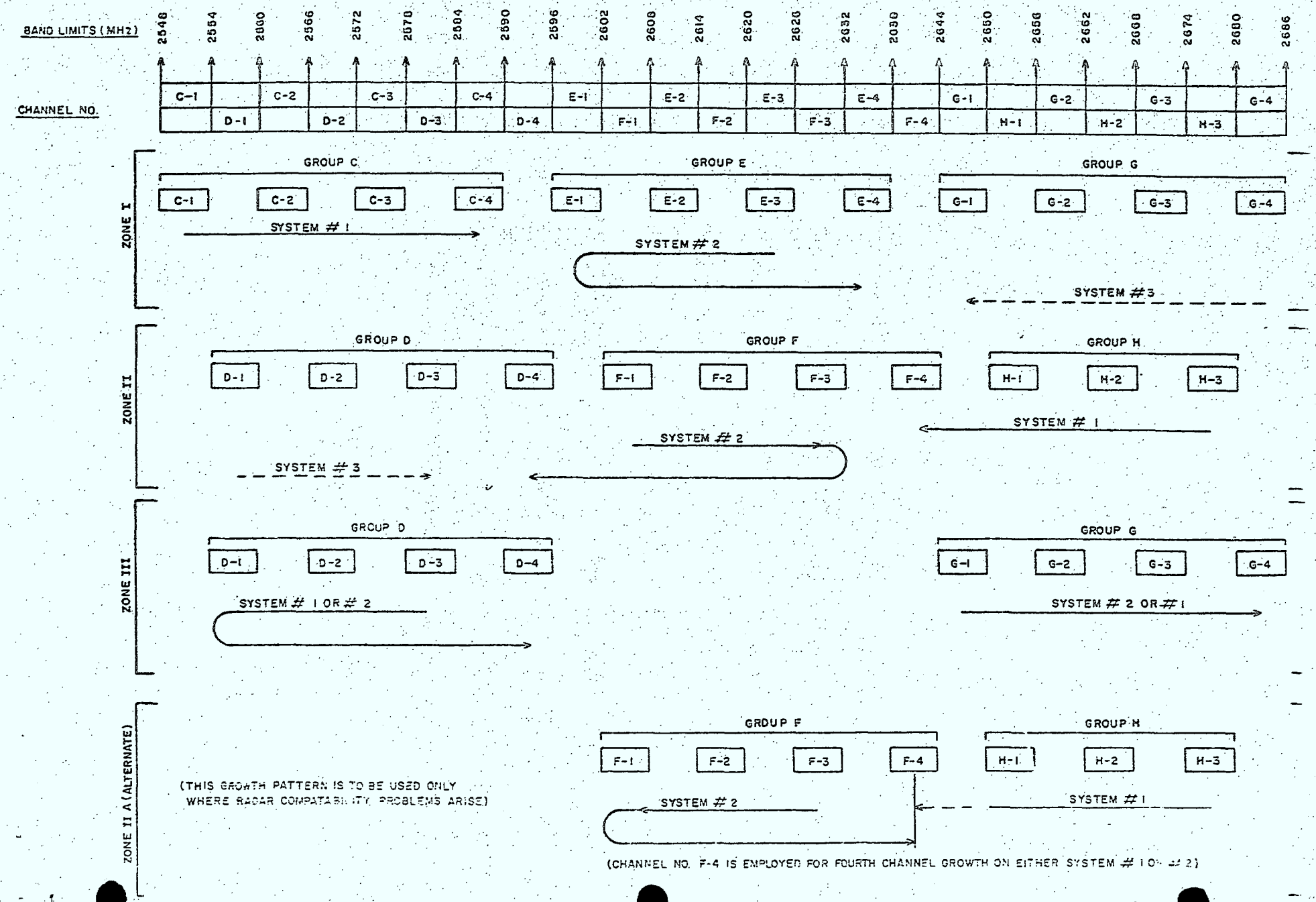
SYSTEMS IN ADJACENT ZONES I, II AND III MAY BE INTERCONNECTED BY ONE OF THE FOLLOWING METHODS:

a) THE USE OF THE STANDARD MICROWAVE RADIO RELAY SYSTEMS AT FREQUENCIES SPECIALLY ALLOCATED FOR THIS PURPOSE IN THE 7 GH_Z BAND.

b) THE DIRECT "OFF THE AIR" PICKUP OF ONE OR MORE CHANNELS AND THE RETRANSMISSION OF THESE SIGNALS OVER ANOTHER GROUP OF ITV CHANNELS. WHEN LOW DIRECTIVITY ANTENNAS ARE USED THE EQUIVALENT ISOTROPICALLY RADIATED POWER SHOULD NOT EXCEED 25 DBW. IN ADDITION THE SYSTEMS IN ZONES I AND II MUST NOT HAVE GROWN TO A SIZE THAT WOULD PROHIBIT THIS TYPE OF INTERCONNECTION. WHEN EITHER ZONE HAS CHANNELS IN SYSTEM #3 IN USE THE DEPARTMENT WILL ONLY CONSIDER THE CONTINUED USE OF THIS METHOD OF INTERCONNECTION IF THE LICENCEE OF THE INTERCONNECTING LINK CAN SHOW THAT HIS SYSTEM WILL NOT INTERFERE WITH OR BE INTERFERED FROM OTHER ITV STATIONS.

P. 76

CHANNEL ALLOCATIONS



Zone Allocations

Zone	Zone Classification	Center of Zone	Radius of Zone (Miles)
Victoria	I	N 48° 26' - W 123° 20'	30
Vancouver	I	N 49° 15' - W 123° 5'	30
Edmonton	I	N 53° 34' - W 113° 30'	30
Calgary	I	N 51° 04' - W 114° 04'	30
Lethbridge	I	N 49° 43' - W 112° 50'	30
Saskatoon	II A	N 52° 08' - W 106° 40'	30
Regina	I	N 50° 28' - W 104° 38'	30
Winnipeg	I	N 49° 54' - W 97° 08'	30
Lakehead Area	II A	N 48° 25' - W 89° 14'	30
Sudbury	I	N 46° 29' - W 81° 00'	30
Windsor	II	N 42° 20' - W 83° 00'	30
Sarnia	II	N 42° 58' - W 82° 24'	25
Chatham	I	N 42° 25' - W 82° 10'	15
London	I	N 42° 59' - W 81° 15'	30
Kitchener	I	N 43° 28' - W 80° 32'	30
Hamilton	II	N 43° 16' - W 79° 50'	30
Niagara Falls	III	N 43° 05' - W 79° 10'	20
Toronto	I	N 43° 41' - W 79° 26'	30
Oshawa	II	N 43° 54' - W 78° 52'	30
Barrie	II	N 44° 24' - W 79° 40'	30
Peterborough	I	N 44° 18' - W 78° 20'	30
Belleville	II A	N 44° 10' - W 77° 23'	30
Kingston	II A	N 44° 14' - W 76° 30'	30

Cont'd

Name	Zone Classification	Center of Zone	Radius of Zone (Miles
Cornwall	II A	N 45° 02' - W 74° 44'	30
Ottawa	II A	N 45° 26' - W 75° 42'	30
Montreal	I	N 45° 30' - W 73° 36'	30
Sherbrooke	I	N 45° 24' - W 71° 53'	30
Trois Rivieres	I	N 46° 21' - W 72° 33'	30
Quebec	I	N 46° 49' - W 71° 13'	30
Chicoutimi	I	N 48° 26' - W 71° 03'	30
Fredericton	I	N 45° 58' - W 66° 38'	30
Saint John	I	N 45° 17' - W 66° 03'	30
Moncton	I	N 46° 05' - W 64° 47'	30
Halifax	I	N 44° 40' - W 63° 36'	30
Sydney	II A	N 46° 10' - W 60° 10'	30
St. Johns	I	N 47° 34' - W 52° 42'	30

5925 - 6425 MH_Z

THE MAIN ROUTE OF THE FIRST 6 GH_Z SYSTEM IN AN AREA SHOULD PREFERABLY USE THE FREQUENCIES IN THE A GROUP AS SHOWN ON PAGE 80. OTHER SYSTEMS WHICH COULD POTENTIALLY CONFLICT WITH AN EXISTING A TYPE SYSTEM SHOULD CONSIDER THE USE OF FREQUENCIES IN THE B GROUP, AS SHOWN ON PAGE 80. THE FREQUENCIES ASSIGNED TO A MAIN ROUTE SYSTEM SHOULD BE RE-USED ON THE BRANCHING OR SPUR ROUTES.

SUPERVISORY, CONTROL, AND MAINTENANCE INFORMATION MAY BE CARRIED ON THE FOLLOWING FACILITIES, LISTED IN ORDER OF PREFERENCE:

A) WIRELINE CIRCUITS OR IN THE SUB-BASEBAND OF THE MAIN RADIO RELAY SYSTEM

B) IN THE BASEBAND OF THE MAIN RADIO RELAY SYSTEM ABOVE THE REGULAR TRAFFIC BAND

C) IN THE SAME RF BAND, ON FREQUENCIES DESIGNATED FOR AUXILIARY RADIO RELAY SYSTEMS. CHANNEL CARRIER FREQUENCIES FOR AUXILIARY RADIO RELAY SYSTEMS ARE GIVEN ON PAGE 80.

D) IN ANOTHER FREQUENCY BAND ALLOCATED TO LOW CAPACITY SYSTEMS.

SYSTEMS SUBMITTED FOR LICENCING SHOULD EVENTUALLY HAVE THE CAPABILITY TO TRANSMIT AT LEAST 600 TELEPHONE CHANNELS OR THE EQUIVALENT LOADING, OR TV ON EACH RADIO CHANNEL.

A RATIO OF THREE WORKING TO ONE PROTECTION WILL BE PERMITTED IN THIS BAND AT FULL CAPACITY THE SYSTEM WILL HAVE 6 WORKING CHANNELS AND 2 PORTECTION CHANNELS.

Group A

Channel Carrier Frequencies

Channel No.	Frequency (MHz)
1	5945.20
2	5974.85
3	6004.50
4	6034.15
5	6063.80
6	6093.45
7	6123.10
8	6152.75
1'	6197.24
2'	6226.89
3'	6256.54
4'	6286.19
5'	6315.84
6'	6345.49
7'	6375.14
8'	6404.79

Group B

Channel Carrier Frequencies

Channel No.	Frequency (MHz)
1	5930.37
2	5960.02
3	5989.67
4	6019.32
5	6048.97
6	6078.62
7	6108.27
8	6137.92
1'	6182.41
2'	6212.06
3'	6241.71
4'	6271.36
5'	6301.01
6'	6330.66
7'	6360.31
8'	6389.96

Carrier Frequencies for Auxiliary Radio-Relay Systems

Type of Modulation	Channel Designation			
	Go		Return	
	a	b	a'	b'
FM	5926.1	6171.9	6178.1	6423.9
AM	5925.5	6172.5	6177.5	6424.5

THE TRANSMIT POWER DELIVERED TO THE ANTENNA INPUT SHALL NOT EXCEED THE FOLLOWING VALUES: -

a) 5 WATTS - FOR SYSTEMS WITH CAPACITIES UP TO 1260 VOICE CHANNELS PER RF CHANNEL

b) 10 WATTS - FOR SYSTEMS WITH CAPACITIES FROM 1261 - 1800 VOICE CHANNELS PER RF CHANNEL

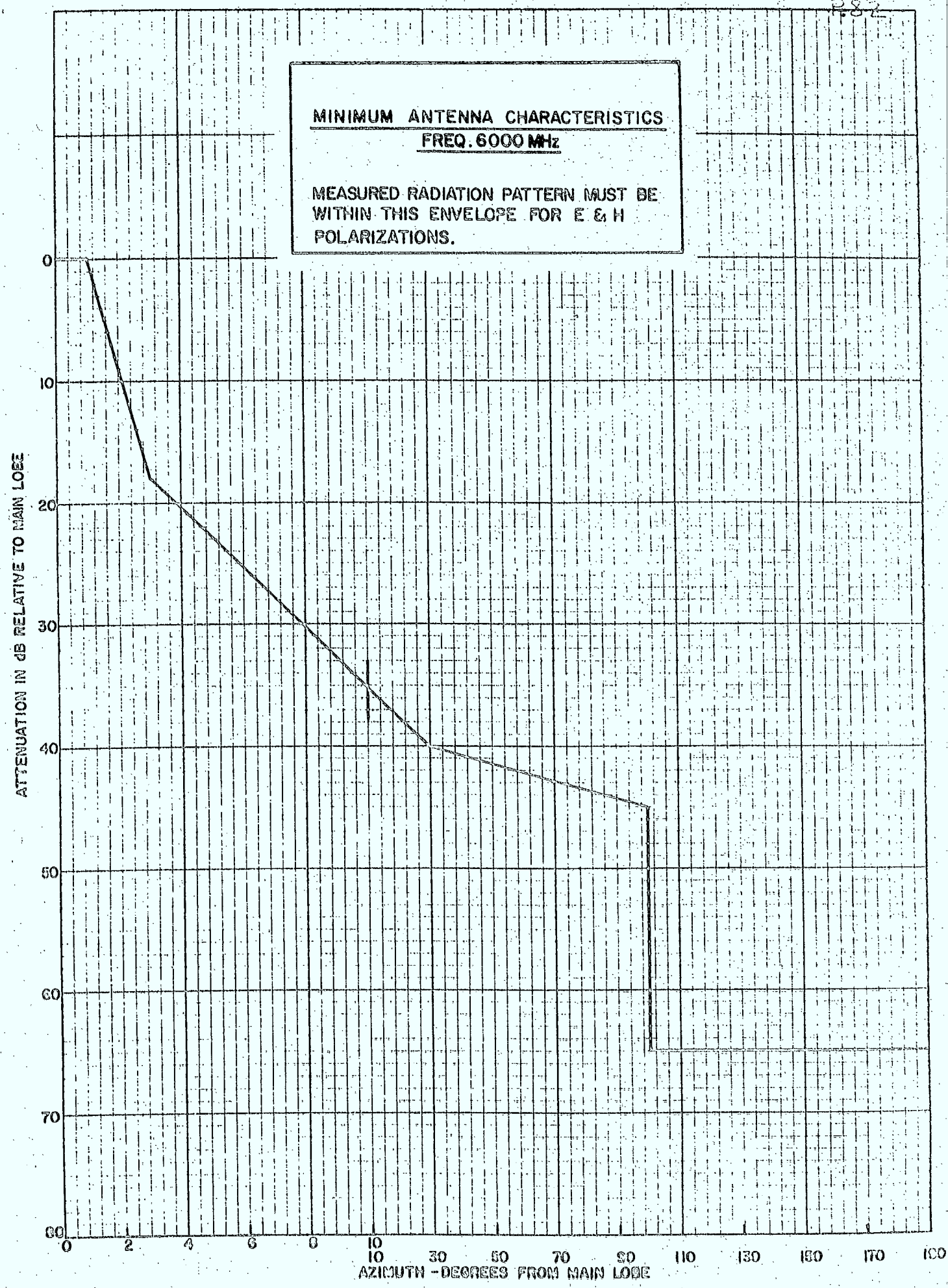
c) IN NO EVENT SHALL THE POWER DELIVERED TO THE ANTENNA BE PERMITTED TO EXCEED 20 WATTS.

THE TRANSMITTED FREQUENCY SHALL BE MAINTAINED WITHIN $\pm$ 0.02% OF THE ASSIGNED FREQUENCY.

THE SMOOTHED DIRECTIVITY PATTERN OF THE ANTENNA FOR BOTH POLARIZATION MUST REMAIN WITHIN THE ENVELOPE SHOWN IN PAGE 82.

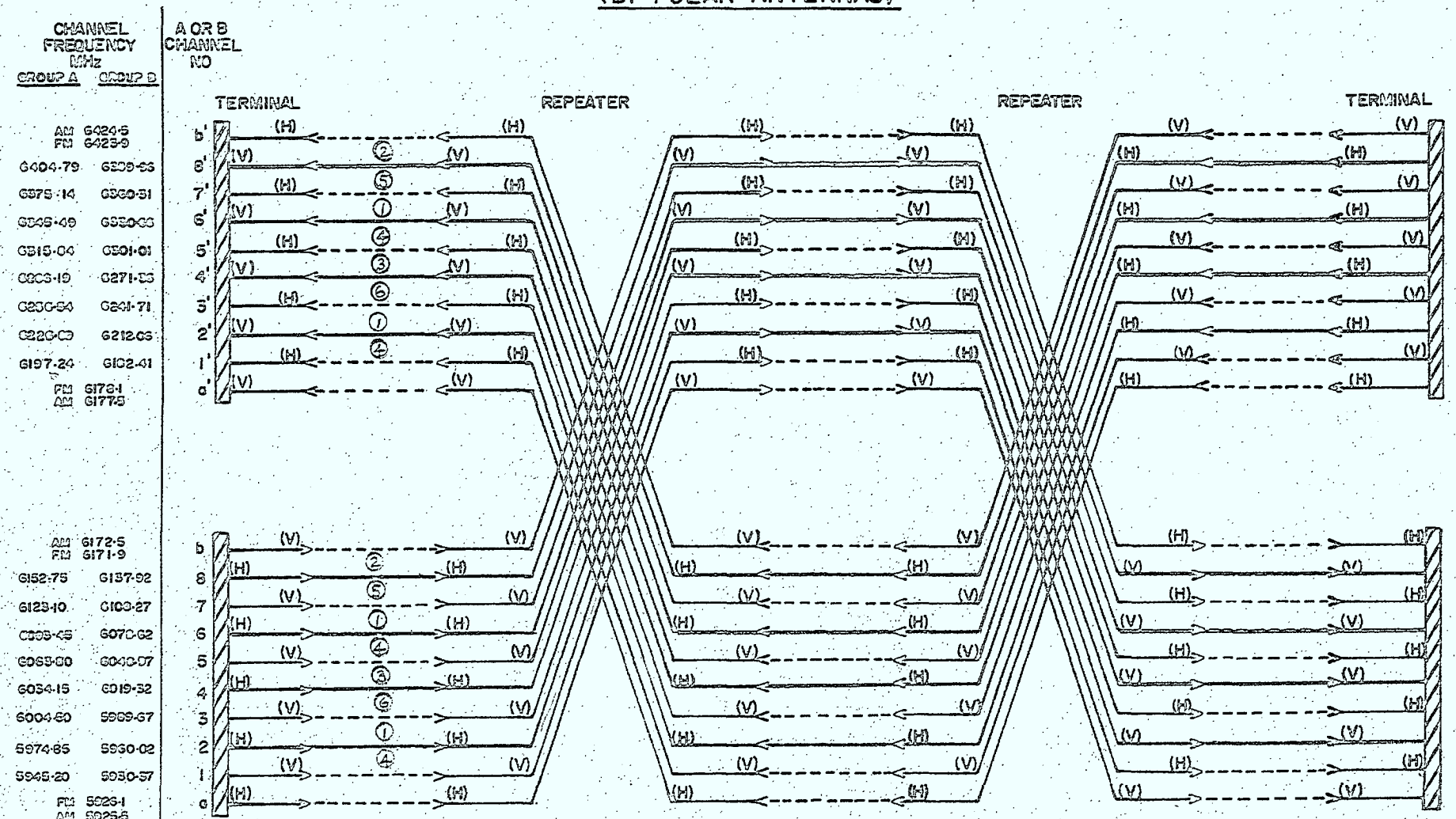
IT SHOULD BE NOTED THAT THE CENTER OF THE MAJOR LOBE OF ANY ANTENNA MUST NOT BE DIRECTED AT LESS THAN 2 DEGREES FROM THE GEOSTATIONARY SATELLITE ORBIT.

FULLY DEVELOPED FREQUENCY PLANS ARE SHOWN ON PAGES 83 AND 84. THE CIRCLED NUMBERS SHOW THE ORDER OF GROWTH PREFERRED ON PAGE 83 AND ALTERNATE ON PAGE 84. THE SOLID LINES ON BOTH PAGES INDICATE THE MAXIMUM NUMBER OF CHANNELS THAT COULD BE USED ON A SINGLE ANTENNA OPERATION.

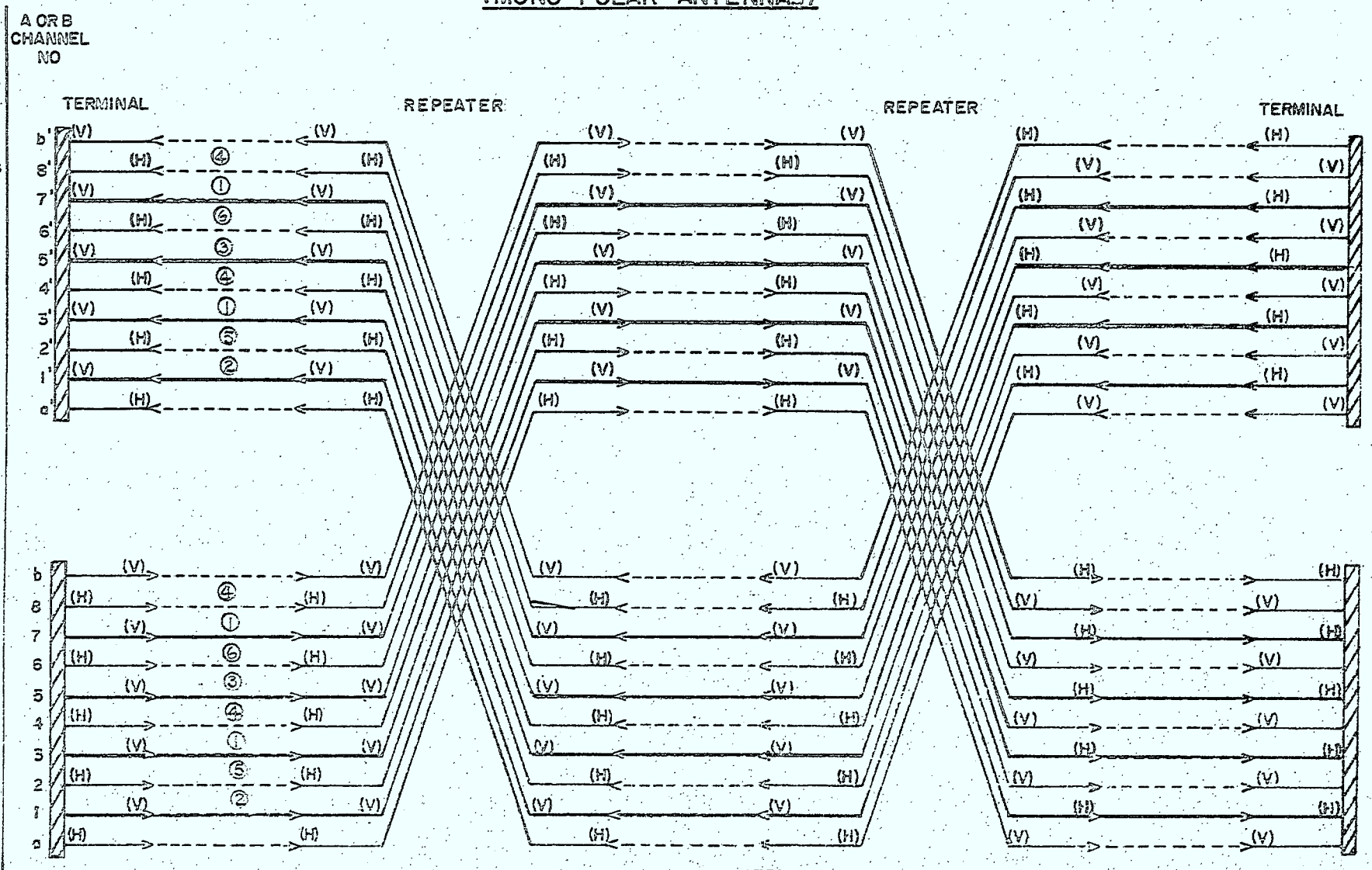

MINIMUM ANTENNA CHARACTERISTICS
FREQ. 6000 MHz
MEASURED RADIATION PATTERN MUST BE WITHIN THIS ENVELOPE FOR E & H POLARIZATIONS.
ATTENUATION IN dB RELATIVE TO MAIN LOBE
0
10
20
30
40
50
60
70
80
0
2
4
6
8
10
10
30
50
70
90
110
130
150
170
180
AZIMUTH - DEGREES FROM MAIN LOBE

RADIO FREQUENCY CHANNEL ARRANGEMENT

(BI-POLAR ANTENNAS)



RADIO FREQUENCY CHANNEL ARRANGEMENT
(MONO-POLAR ANTENNAS)



NOTES-

1. CHANNELS a, b, a' AND b' ARE AUXILLIARY CHANNELS.
2. H- DENOTES HORIZONTAL POLARIZATION
   V- DENOTES VERTICAL POLARIZATION

3500-4200 MHz

THIS BAND ALLOWS THE FULL DEVELOPMENT OF 16 TWO-WAY RF CHANNELS WITH A CAPACITY ON EACH RF CHANNEL OF UP TO 1260 VOICE CIRCUITS OR THE EQUIVALENT LOADING OR TV. THE OTHER ARRANGEMENT PERMITS 8 TWO-WAY RF CHANNELS WITH A CAPACITY PER RF CHANNEL EXCEEDING 1260 AND UP TO 2700 VOICE CIRCUITS OR THE EQUIVALENT LOADING OR MULTIPLE TV. THE FREQUENCIES ASSIGNED TO MAIN ROUTE SYSTEM SHOULD BE RE-USED ON THE BRANCHING OF SPUR ROUTES.

THE LOWER FOUR FREQUENCIES 3550, 3570, 3590 AND 3610 MHz, ALTHOUGH EXPOSED TO POSSIBLE INTERFERENCE IN CERTAIN AREAS CLOSE TO THE U.S./CANADA BORDER OR COASTAL AREAS, MAY BE USED SUBJECT TO SATISFACTORY CO-ORDINATION WITH THE U.S.

SYSTEMS SUBMITTED FOR LICENCING MUST HAVE EVENTUALLY THE CAPABILITY TO TRANSMIT AT LEAST 600 TELEPHONE CHANNELS, OR THE EQUIVALENT LOADING ON EACH R.F. CHANNEL.

THE FOLLOWING PROTECTION CHANNEL ARRANGEMENTS ARE PERMISSIBLE:

a) ONE PROTECTION CHANNEL FOR ONE TO SEVEN WORKING CHANNELS

b) TWO PROTECTION CHANNELS FOR EIGHT TO FOURTEEN WORKING CHANNELS.

SUPERVISORY, CONTROL, AND MAINTENANCE INFORMATION FOR THE MAIN RADIO-RELAY SYSTEM OPERATING IN THIS BAND MAY BE CARRIED ON THE FOLLOWING FACILITIES LISTED IN ORDER OF PREFERENCE: -

a) WIRELINE CIRCUITS OR IN THE SUB-BASEBAND OF THE MAIN RADIO-RELAY SYSTEM.

b) IN THE BASEBAND OF THE MAIN RADIO-RELAY SYSTEM ABOVE THE REGULAR TRAFFIC BAND.

c) IN ANOTHER FREQUENCY BAND ALLOCATED TO LOW CAPACITY SYSTEMS.

THE TRANSMITTER POWER DELIVERED TO THE ANTENNA INPUT SHALL NOT EXCEED THE FOLLOWING VALUES: -

a) 5 WATTS - FOR SYSTEMS WITH CAPACITIES OF 600-960 TELEPHONE CIRCUITS, OR EQUIVALENT, OR TV PER RF CHANNEL.

b) 10 WATTS - FOR SYSTEMS WITH CAPACITIES OF GREATER THAN 960 CIRCUITS, OR EQUIVALENT, OR MULTIPLE TV PER RF CHANNEL.

c) IN NO EVENT SHALL THE POWER DELIVERED TO THE ANTENNA BE PERMITTED TO EXCEED 20 WATTS PER RF CHANNEL.

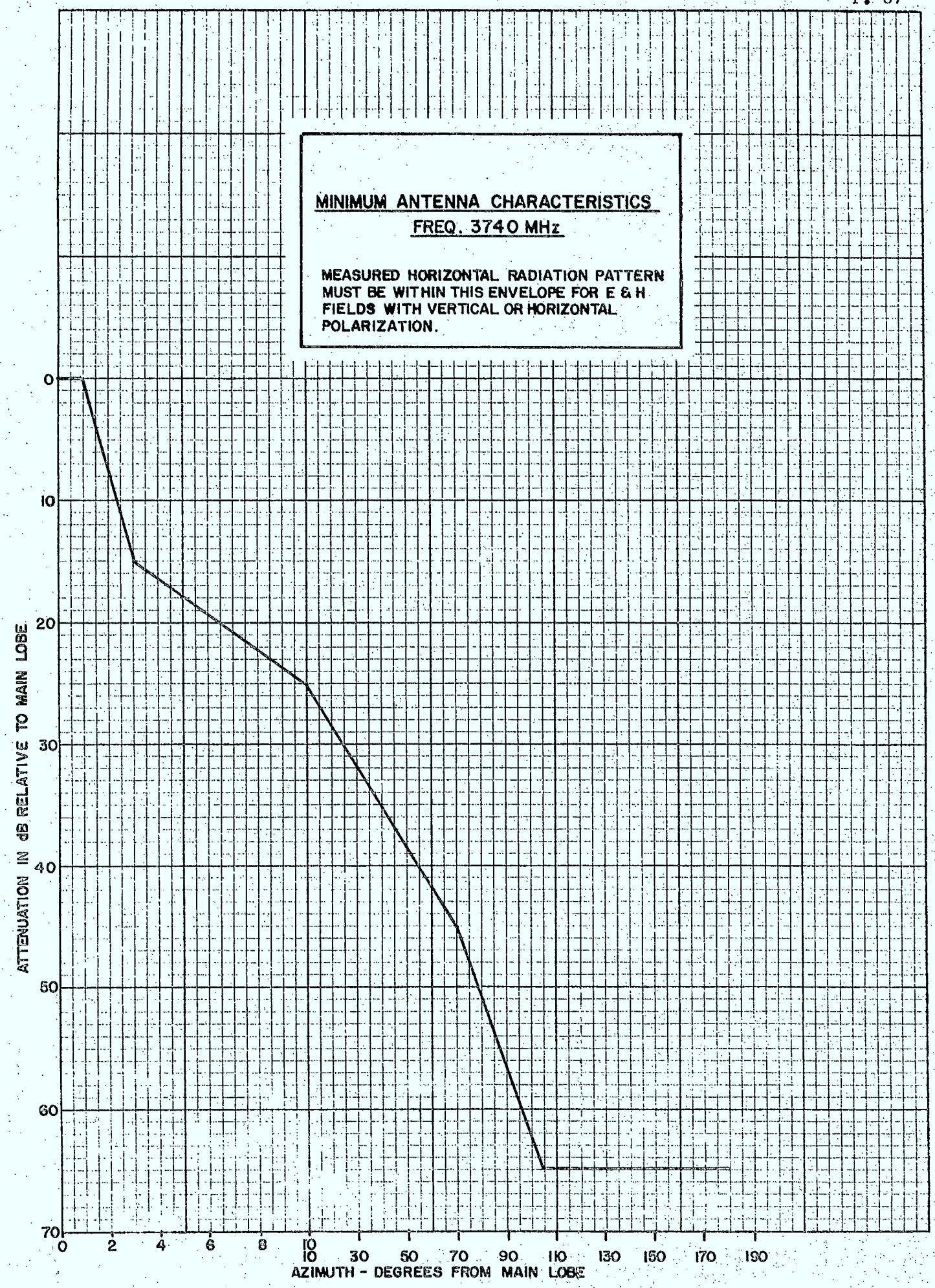
THE CARRIER FREQUENCY SHOULD BE MAINTAINED WITHIN $\pm$ 0.02% OF THE ASSIGNED FREQUENCY.

THE SMOOTHED HORIZONTAL DIRECTIVITY PATTERN OF THE ANTENNA FOR BOTH POLARIZATIONS MUST REMAIN WITHIN THE ENVELOPE SHOWN ON PAGE 87.

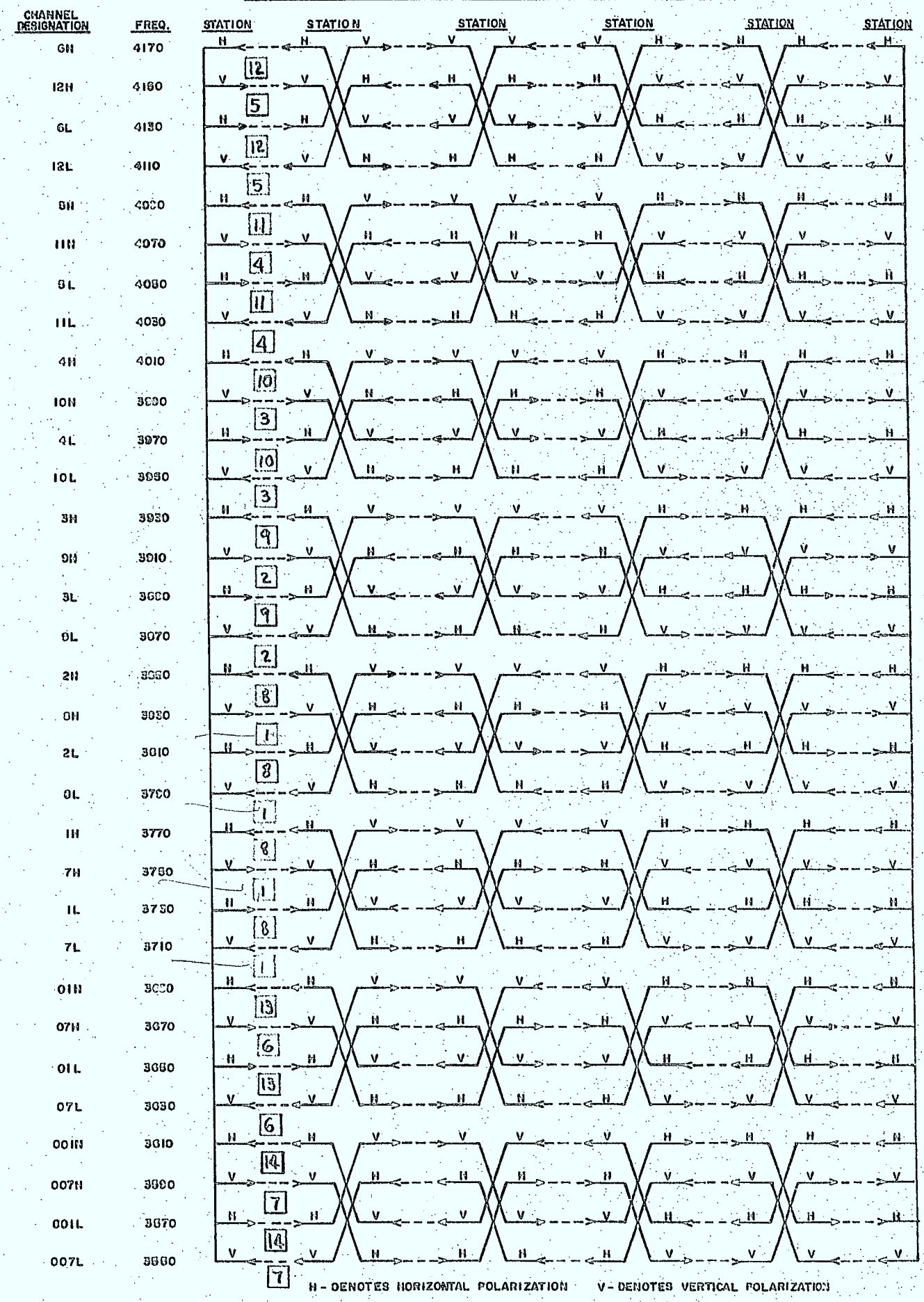
THE CENTRE OF THE MAJOR LOBE OF ANY ANTENNA SHOULD NOT BE DIRECTED AT LESS THAN 2 DEGREES AWAY FROM THE GEOSTATIONARY SATELLITE ORBIT.

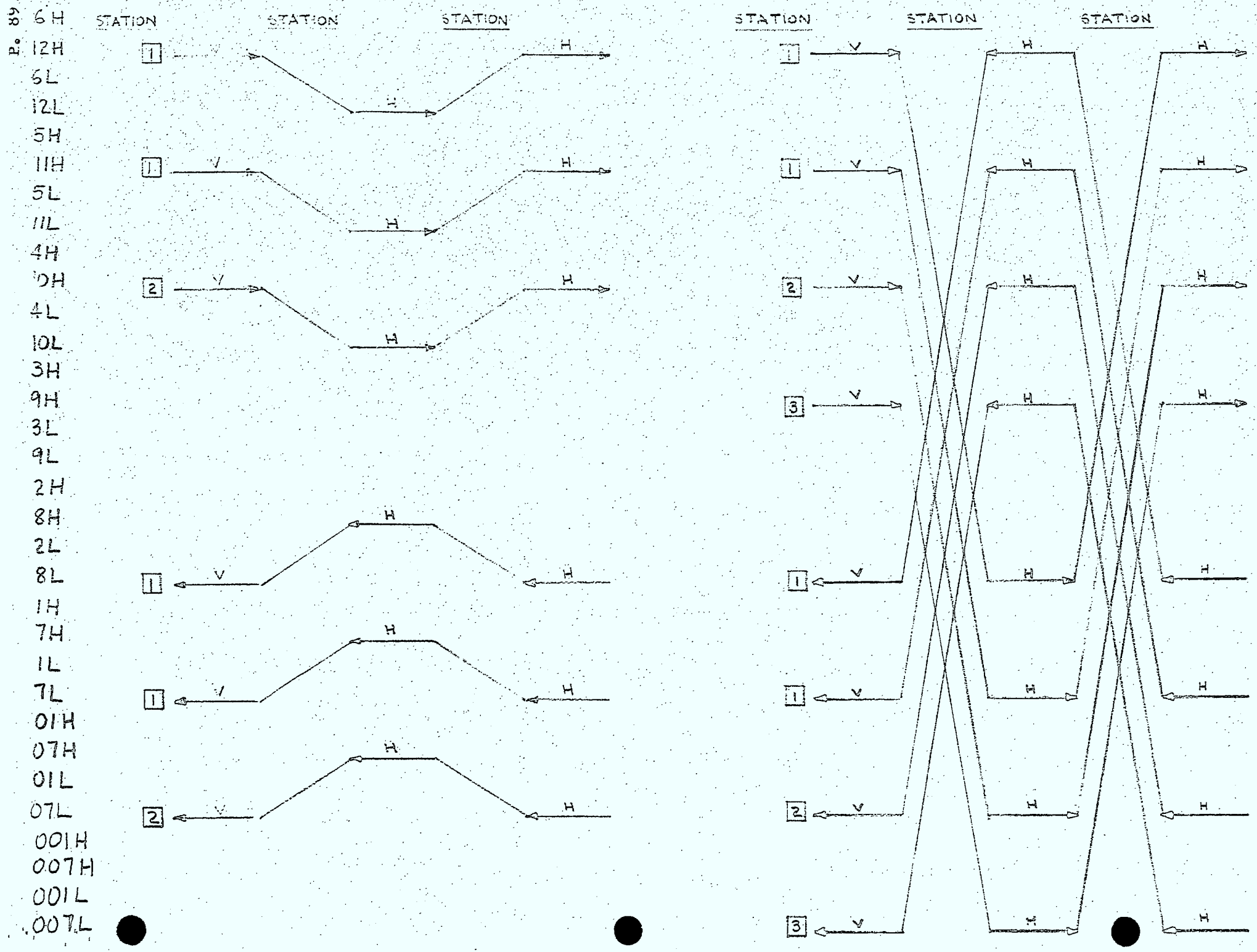
PAGE 88 SHOWS A FULLY DEVELOPED FREQUENCY PLAN, AND THE NUMBERS IN THE SMALL SQUARES INDICATE THE PREFERRED ORDER OF GROWTH.

PAGE 85 SHOWS THE SINGLE ANTENNA OPERATION FOR THREE CHANNELS AND FOUR CHANNELS.


MINIMUM ANTENNA CHARACTERISTICS
FREQ. 3740 MHz
MEASURED HORIZONTAL RADIATION PATTERN MUST BE WITHIN THIS ENVELOPE FOR E & H FIELDS WITH VERTICAL OR HORIZONTAL POLARIZATION.
ATTENUATION IN dB RELATIVE TO MAIN LOBE
0
10
20
30
40
50
60
70
0
2
4
6
8
10
10
30
50
70
90
110
130
150
170
190
AZIMUTH - DEGREES FROM MAIN LOBE

FREQUENCY AND POLARIZATION ARRANGEMENTS




STATION
STATION
STATION
STATION
STATION
STATION
6H
12H
6L
12L
5H
11H
5L
11L
4H
10H
4L
10L
3H
9H
3L
9L
2H
8H
2L
8L
1H
7H
1L
7L
01H
07H
01L
07L
001H
007H
001L
007L
V
H
1
2
3

6425-6590 MH_Z AND 6770-6930 MH_Z

THE BANDS 6425-6590/6770 - 6930 MH_Z ARE PARTICULARLY VALUABLE FOR RADIO-RELAY SYSTEMS OPERATING IN THE CO-ORDINATION ZONE OF EARTH STATIONS IN THE COMMUNICATION-SATELLITE SERVICE BECAUSE OF ITS "NON-SHARING" ASPECT WITH COMMUNICATION SATELLITE SYSTEMS. THE FREQUENCY PLAN COULD BE ARRANGED IN TWO FASHIONS. ONE ARRANGEMENT IS BASED ON A 20 MH_Z CHANNELLING BANDWIDTH AND WILL PROVIDE 8 TWO-WAY RF CHANNELS FOR MULTIPLE HOP RADIO-RELAY SYSTEMS WITH A CAPACITY ON EACH RF CHANNEL OF UP TO 1260 SSB FDM TELEPHONY CHANNELS OR THE EQUIVALENT LOADING OR TV. THE OTHER ARRANGEMENT IS BASED ON A 40 MH_Z CHANNELLING BANDWIDTH AND WILL PROVIDE 4 TWO-WAY RF CHANNELS FOR MULTIPLE HOP RADIO-RELAY SYSTEMS WITH A CAPACITY PER RF CHANNEL EXCEEDING 1260 AND UP TO 2700 SSB FDM TELEPHONY CHANNELS OR THE EQUIVALENT LOADING OF MULTIPLE TV CHANNELS. THE FREQUENCIES ASSIGNED TO A MAIN ROUTE SYSTEM SHALL BE RE-USED ON THE BRANCHING OR SPUR ROUTES.

THE FOLLOWING PROTECTION CHANNEL ARRANGEMENTS ARE PERMISSIBLE:

a) ONE PROTECTION CHANNEL FOR ONE, TWO OR THREE WORKING CHANNELS.

b) TWO PROTECTION CHANNELS FOR FOUR, FIVE OR SIX WORKING CHANNELS.

SUPERVISORY, CONTROL AND MAINTENANCE INFORMATION MAY BE CARRIED ON THE FOLLOWING FACILITIES, LISTED IN ORDER OF PREFERENCE:

a) WIRELINE CIRCUITS OR IN THE SUB-BASEBAND OF THE MAIN RADIO-RELAY SYSTEM.

b) IN THE BASEBAND OF THE MAIN RADIO-RELAY SYSTEM ABOVE THE REGULAR TRAFFIC BAND.

c) IN ANOTHER FREQUENCY BAND ALLOCATED TO LOW CAPACITY SYSTEMS.

THE TRANSMITTER POWER DELIVERED TO THE ANTENNA INPUT SHALL NOT EXCEED THE FOLLOWING VALUES:

a) FOR SYSTEMS WITH CAPACITIES OF UP TO 1260 SSB FDM TELEPHONY CHANNELS OR EQUIVALENT, PER RF CHANNEL: 5 WATTS (7DBW).

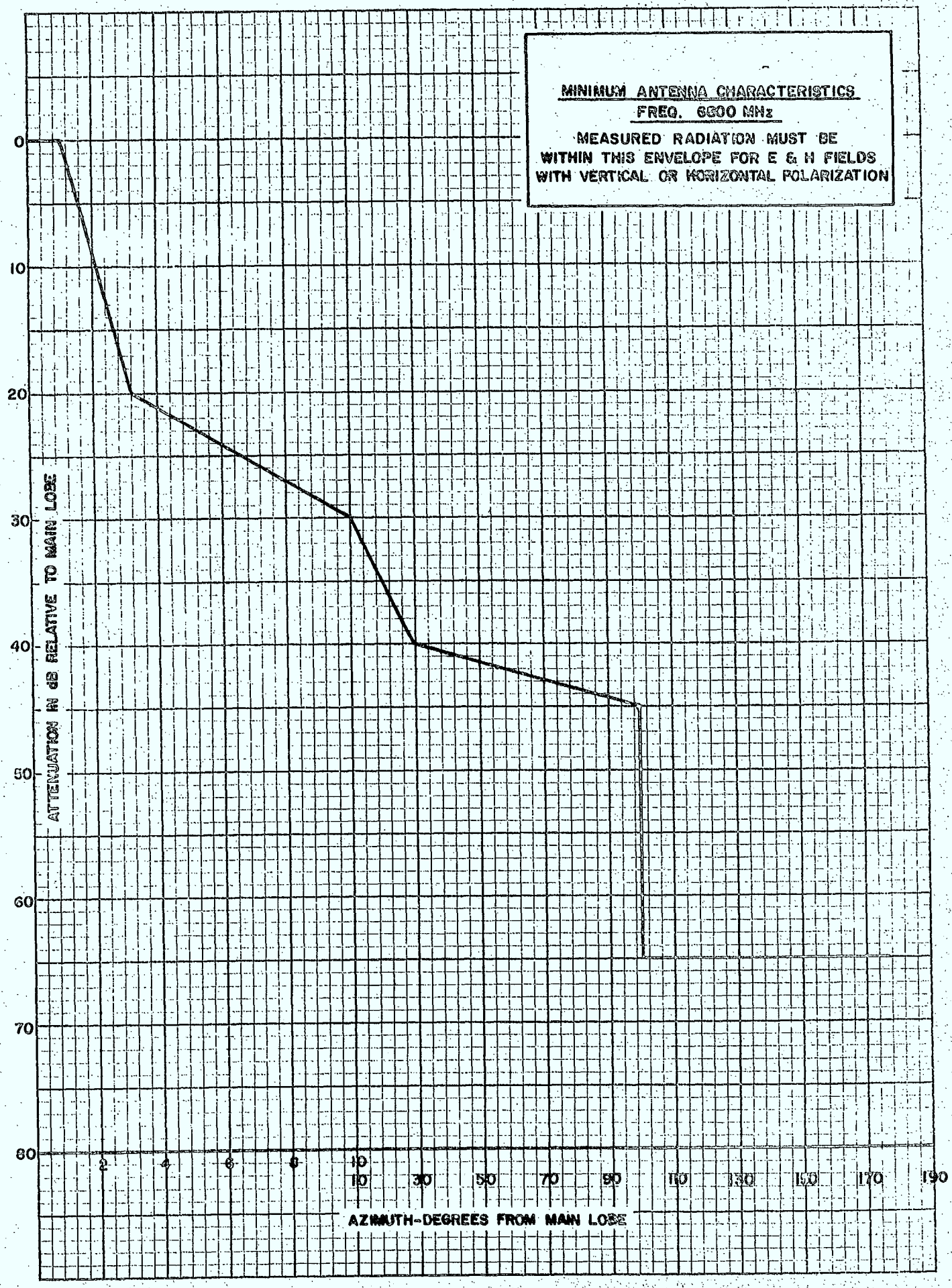
b) FOR SYSTEMS WITH CAPACITIES GREATER THAN 1260 AND UP TO 1800 SSB FDM TELEPHONY CHANNELS OR EQUIVALENT PER RF CHANNEL: 10 WATTS (10 DBW). (IT IS RECOGNIZED WITH CAPACITIES GREATER THAN 1800 SSB FDM TELEPHONY CHANNELS OR EQUIVALENT PER RF CHANNEL THAT POWERS GREATER THAN 10 WATTS (10 DBW) MAY BE NECESSARY).

c) IN NO EVENT SHALL THE POWER DELIVERED TO THE ANTENNA INPUT BE PERMITTED TO EXCEED 20 WATTS (13 DBW) PER RF CHANNEL.

THE CARRIER FREQUENCY SHALL BE MAINTAINED WITHIN ± 0.02% OF THE ASSIGNED FREQUENCY.

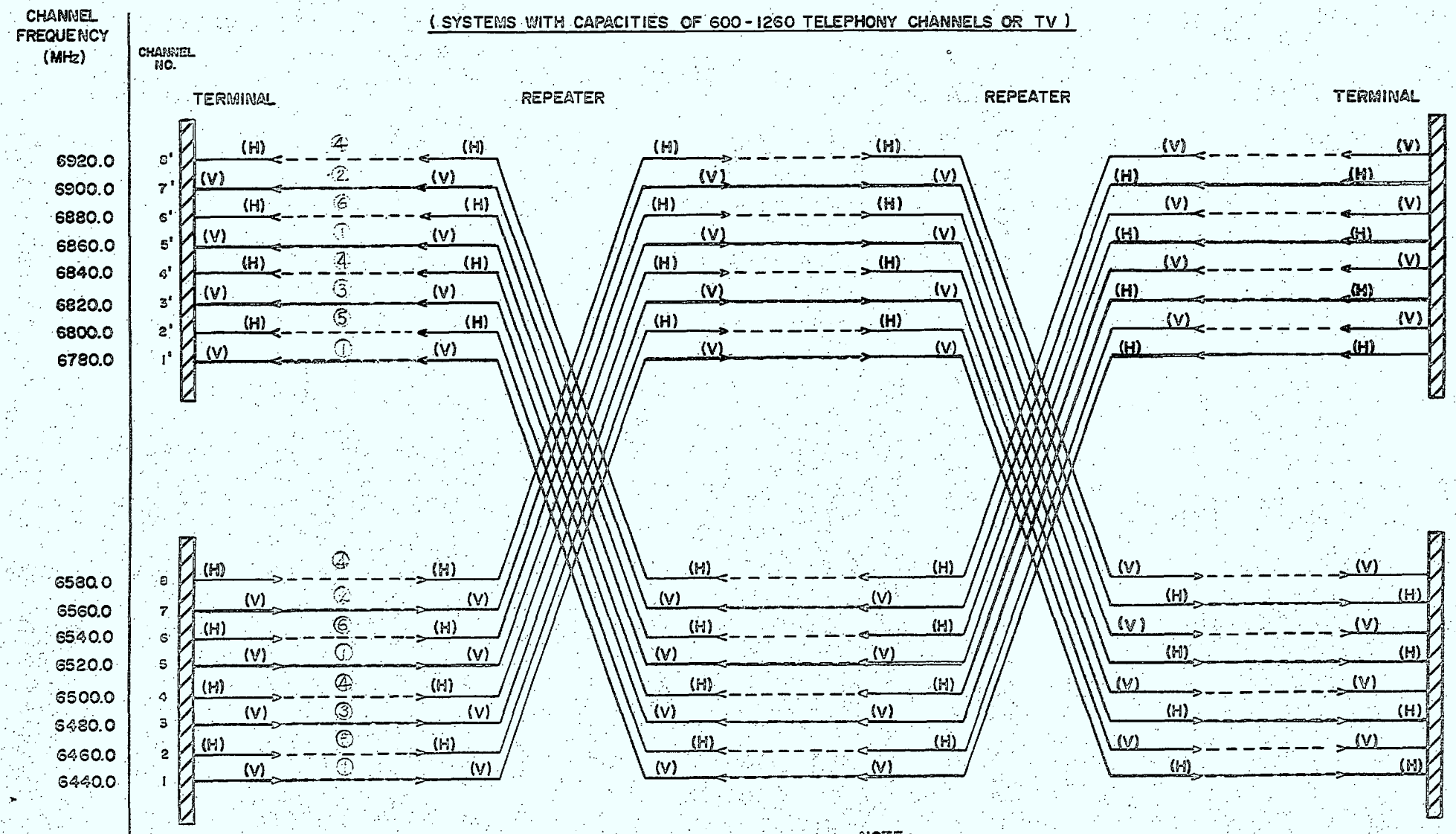
THE SMOOTHED HORIZONTAL DIRECTIVITY PATTERN OF THE ANTENNA FOR BOTH POLARIZATIONS MUST REMAIN WITHIN THE ENVELOPE SHOWN ON PAGE 92.

THE FULLY DEVELOPED FREQUENCY PLANS USING MONO AND DUAL POLARIZATION ARE SHOWN ON PAGES 93 AND 94 RESPECTIVELY. WHILE PAGES 95 AND 96 SHOW FIRST AND SECOND SYSTEMS IN AN AREA AND THEIR CENTRE FREQUENCIES TO BE USED TO ACHIEVE FULL DEVELOPMENT WITH A LOADING OF 1260-2700 CIRCUITS/RF CHANNEL.


MINIMUM ANTENNA CHARACTERISTICS
FREQ. 6600 MHz
MEASURED RADIATION MUST BE
WITHIN THIS ENVELOPE FOR E & H FIELDS
WITH VERTICAL OR HORIZONTAL POLARIZATION
ATTENUATION IN dB RELATIVE TO MAIN LOBE
0
10
20
30
40
50
60
70
80
2
4
6
8
10
10
30
50
70
90
110
130
150
170
190
AZIMUTH-DEGREES FROM MAIN LOBE

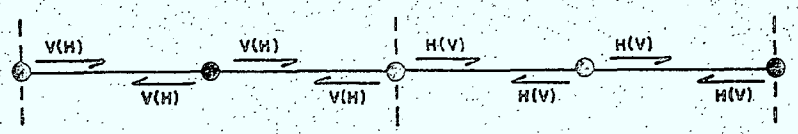
RADIO FREQUENCY CHANNEL ARRANGEMENT (WITH SINGLE POLARISED ANTENNAE)

(SYSTEMS WITH CAPACITIES OF 600 - 1260 TELEPHONY CHANNELS OR TV)



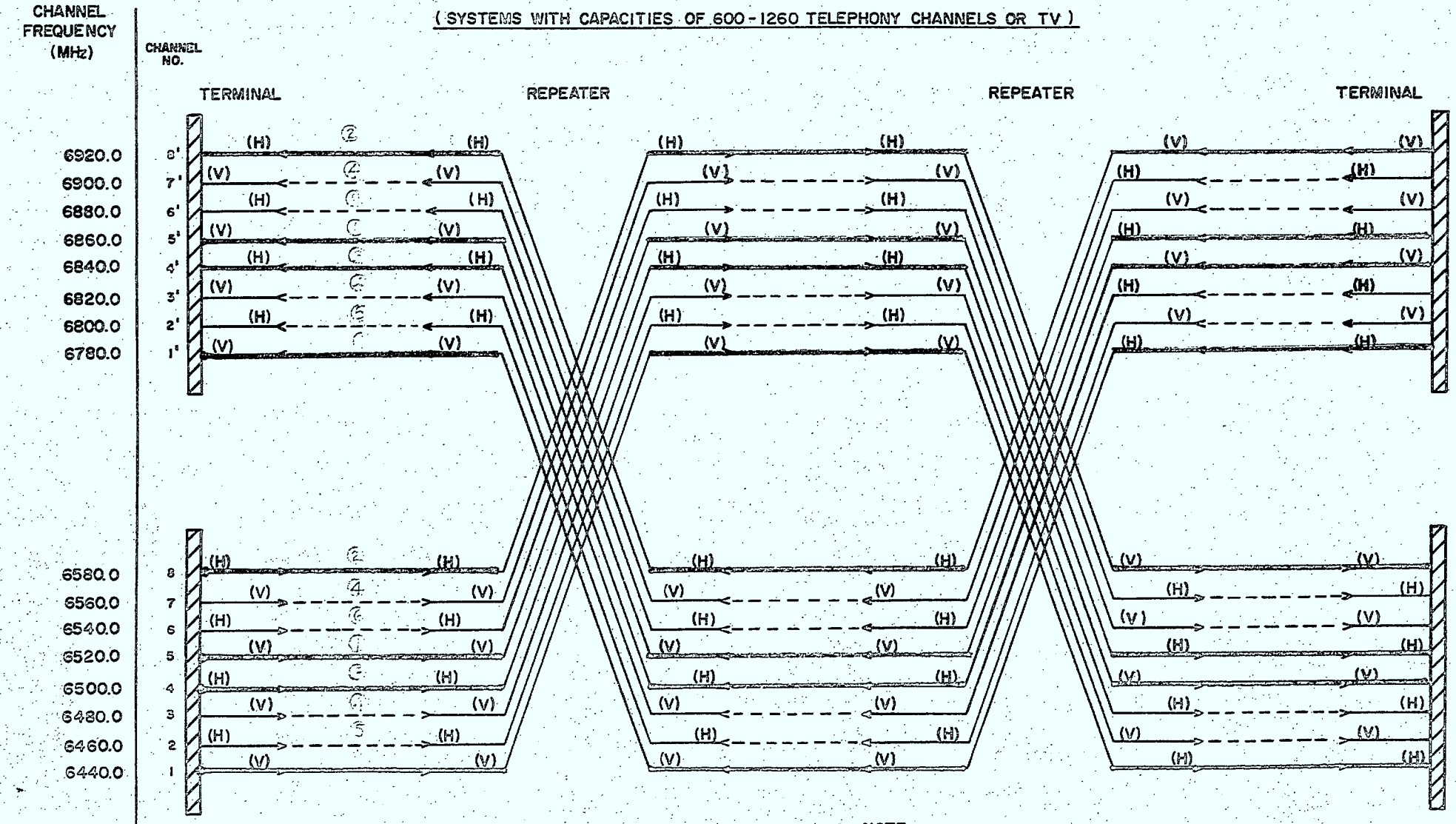
NOTE :-

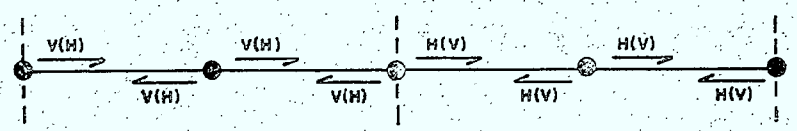
H - DENOTES HORIZONTAL POLARIZATION.
V - DENOTES VERTICAL POLARIZATION.



RADIO FREQUENCY CHANNEL ARRANGEMENT

(SYSTEMS WITH CAPACITIES OF 600 - 1260 TELEPHONY CHANNELS OR TV)





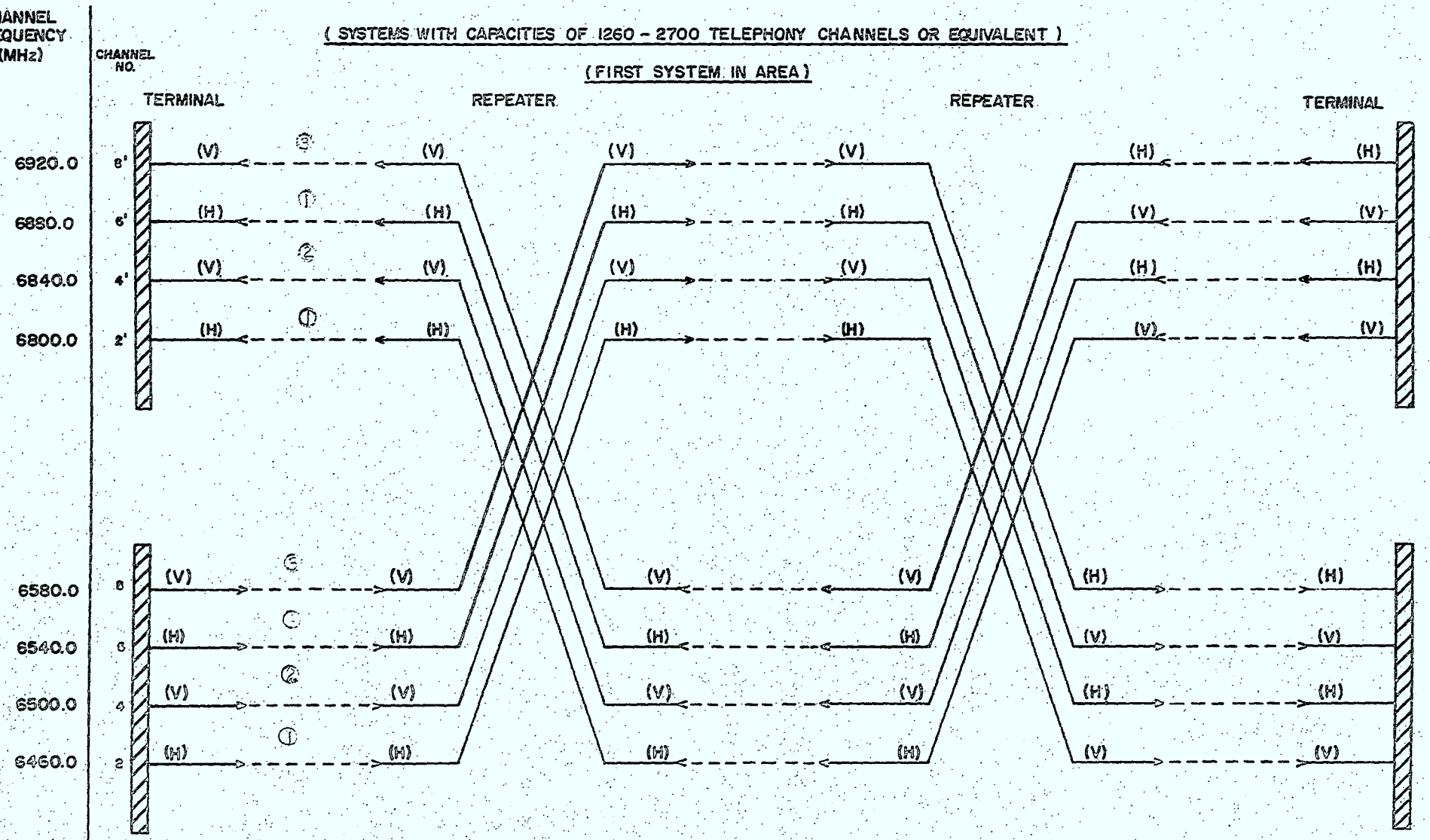
NOTE :-

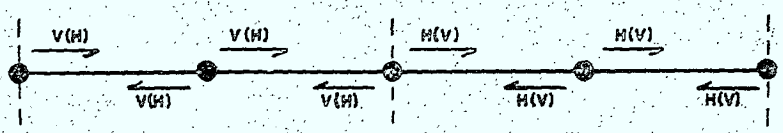
H - DENOTES HORIZONTAL POLARIZATION.
V - DENOTES VERTICAL POLARIZATION.

RADIO FREQUENCY CHANNEL ARRANGEMENT

(SYSTEMS WITH CAPACITIES OF 1260 - 2700 TELEPHONY CHANNELS OR EQUIVALENT)

(FIRST SYSTEM IN AREA)





NOTES:-

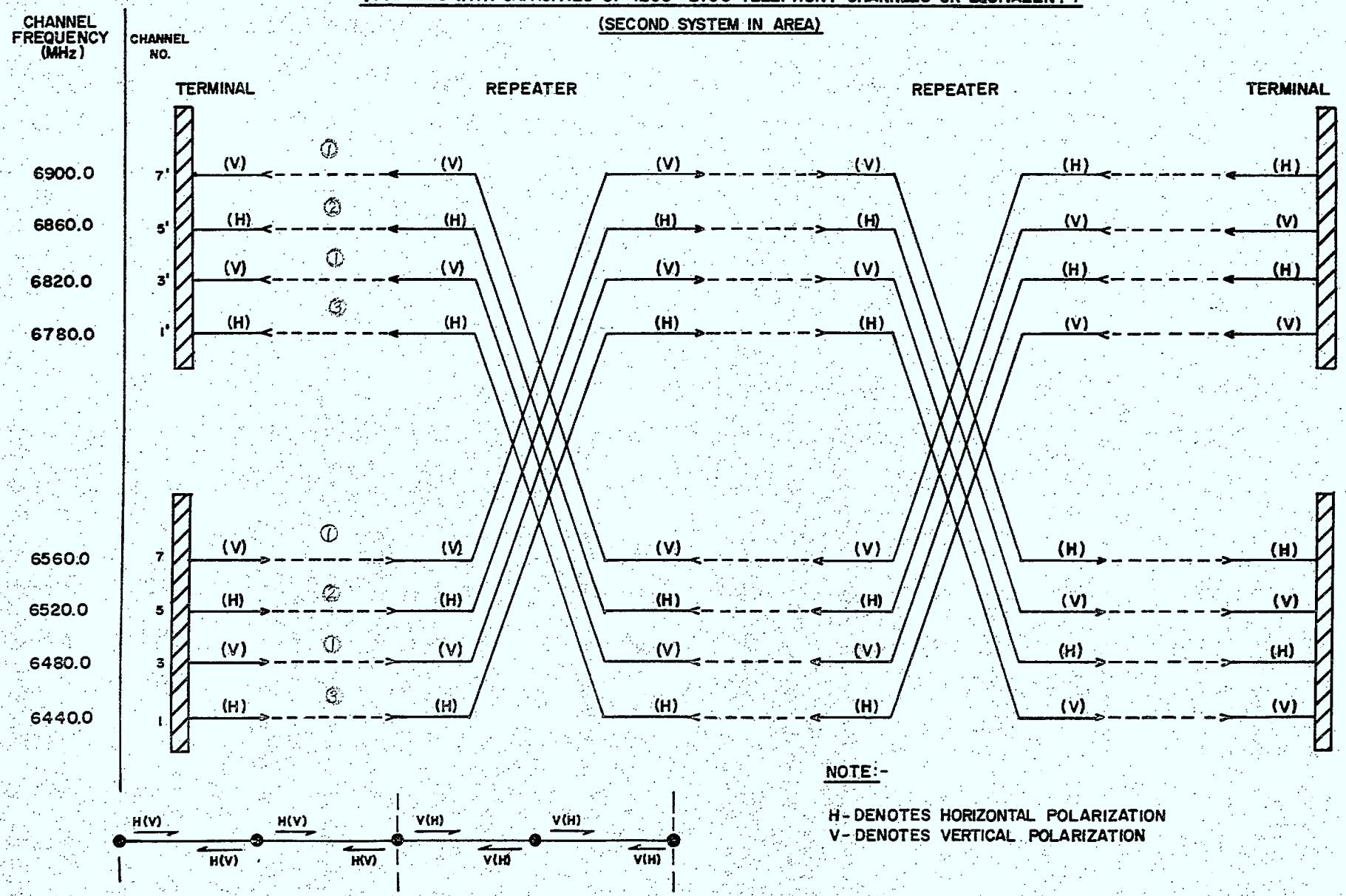
H - DENOTES HORIZONTAL POLARIZATION

V - DENOTES VERTICAL POLARIZATION

RADIO FREQUENCY CHANNEL ARRANGEMENT

(SYSTEMS WITH CAPACITIES OF 1260 - 2700 TELEPHONY CHANNELS OR EQUIVALENT)

(SECOND SYSTEM IN AREA)



NOTE:-

H - DENOTES HORIZONTAL POLARIZATION
V - DENOTES VERTICAL POLARIZATION

1710-1900 MHz

THIS BAND HAS TWO ARRANGEMENTS THAT PROVIDE FOR THE DEVELOPMENT OF RADIO-RELAY SYSTEMS WITH CAPACITIES OF MORE THAN 60 AND UP TO 300 SSB-FM TELEPHONY CHANNELS OR THE EQUIVALENT LOADING, AND FOR SYSTEMS WITH CAPACITIES OF AT LEAST 6 AND UP TO 60 SSB-FDM TELEPHONY CHANNELS OR THE EQUIVALENT LOADING. THESE ARRANGEMENTS ARE DESIGNED FOR SYSTEMS COMPRISED OF ONE WORKING AND ONE PROTECTION R.F. CHANNELS. IF FULL GROWTH AS INDICATED ON PAGE 98 IS NOT ACHIEVED, AND IT IS NOT POSSIBLE TO RE-USE THE SAME SET OF SYSTEM FREQUENCIES WITHIN THE HOP ASSOCIATED WITH A SPUR JUNCTION POINT OTHER UNUSED RF CHANNELS FROM PAGE 98 CAN BE USED FOR THIS PURPOSE. (SEE PAGE 99).

FOR SYSTEMS WITH CAPACITIES OF 6 TO 60 TELEPHONY CHANNELS REFER TO PAGE 100.

MOST 300 CHANNEL CAPACITY SYSTEMS REQUIRE AN ANTENNA FOR EVERY TWO RF DUPLEX CHANNELS.

SUPERVISORY, CONTROL AND MAINTENANCE INFORMATION MAY BE CARRIED IN THE SUB-BASEBAND OF RADIO-RELAY SYSTEM. USUALLY RADIO RELAY SYSTEMS IN THIS BAND CARRY SUPERVISORY, CONTROL AND MAINTENANCE INFORMATION FOR OTHER RADIO-SYSTEMS (i.e. 4GHz AND 6 GHz BANDS).

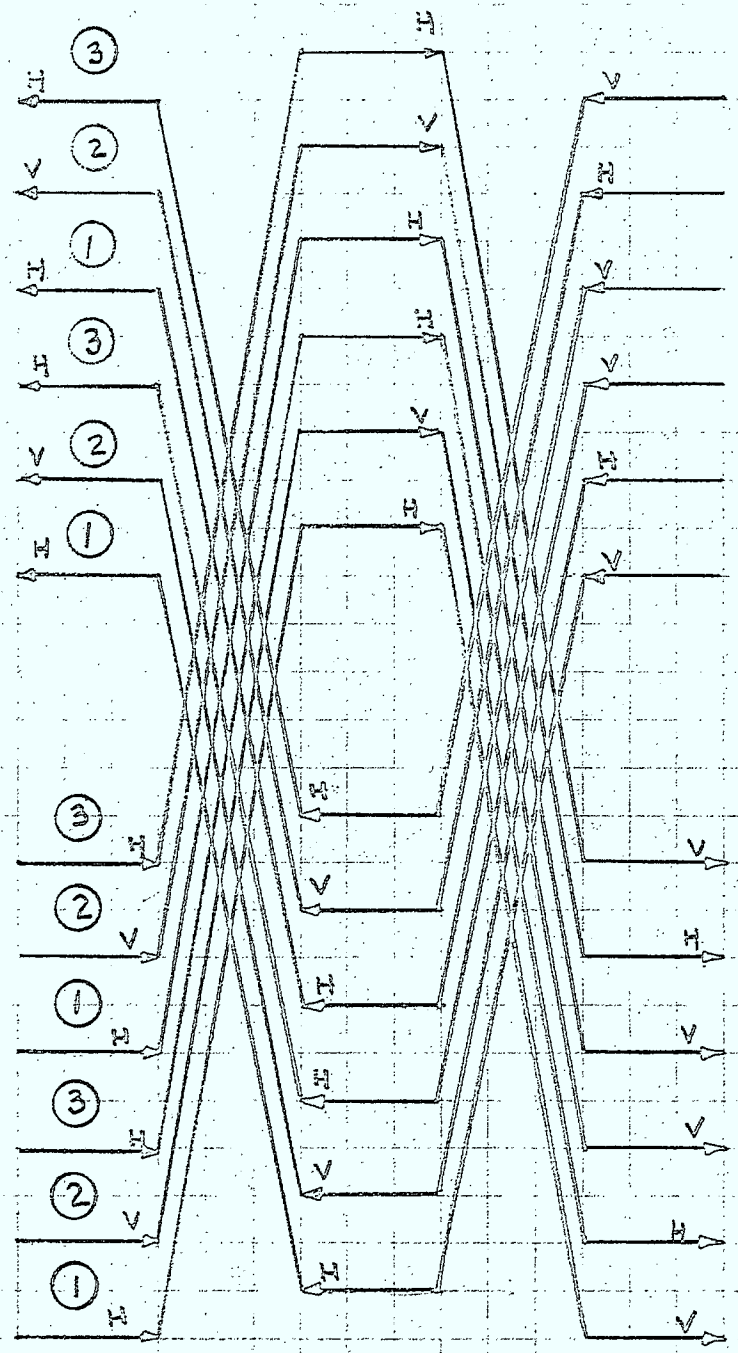
THE TRANSMITTER POWER DELIVERED TO THE ANTENNA INPUT SHALL NOT EXCEED 2 WATTS PER RF CHANNEL.

THE CENTRE FREQUENCY OF THE EMISSION SHALL BE MAINTAINED WITHIN $\pm$ .01% OF THE ASSIGNED FREQUENCY.

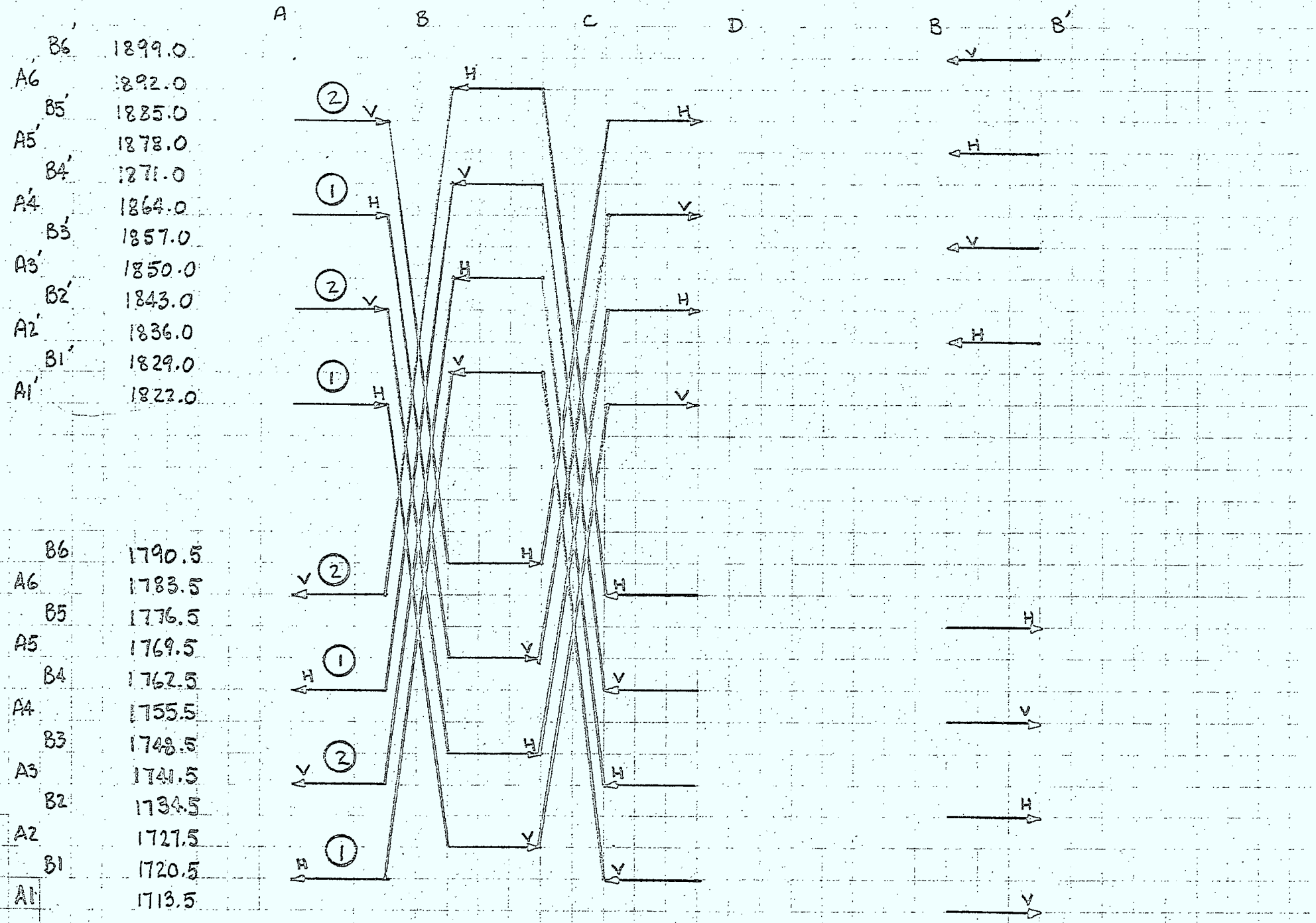
THE SMOOTHED DIRECTIVITY PATTERN OF THE ANTENNA FOR BOTH POLARIZATIONS MUST REMAIN WITHIN THE ENVELOPE SHOWN ON PAGE 101.

60 - 300 Channels loading

	STATION	STATION	STATION
B6'	1899.0		
A6'	1892.0		
B5'	1885.0		
A5'	1878.0		
B4'	1871.0		
A4'	1864.0		
B3'	1857.0		
A3'	1850.0		
B2'	1843.0		
A2'	1836.0		
B1'	1829.0		
A1'	1822.0		
B6	1790.5		
A6	1783.5		
B5	1776.5		
A5	1769.5		
B4	1762.5		
A4	1755.5		
B3	1748.5		
A3	1741.5		
B2	1734.5		
A2	1727.5		
B1	1720.5		
A1	1713.5		



60 – 300 CIRCUIT LOADING



MAIN FREQUENCIES REPEATED
AFTER FIRST HOP IN THE SPUR

6 - 60 TELEPHONY

CHANNEL SYSTEMS

CHANNEL CARRIER FREQUENCIES

GO Channel No.	Frequency (MHz)	RETURN Channel No.	Frequency (MHz)
A7	1717.0	A7'	1825.5
B7	1724.0	B7'	1832.5
A8	1731.0	A8'	1839.5
B8	1738.0	B8'	1846.5
A9	1745.0	A9'	1853.5
B9	1752.0	B9'	1860.5
A10	1759.0	A10'	1867.5
B10	1766.0	B10'	1874.5
A11	1773.0	A11'	1881.5
B11	1780.0	B11'	1888.5
A12	1787.0	A12'	1895.5
B12	1794.0	B12'	1902.5

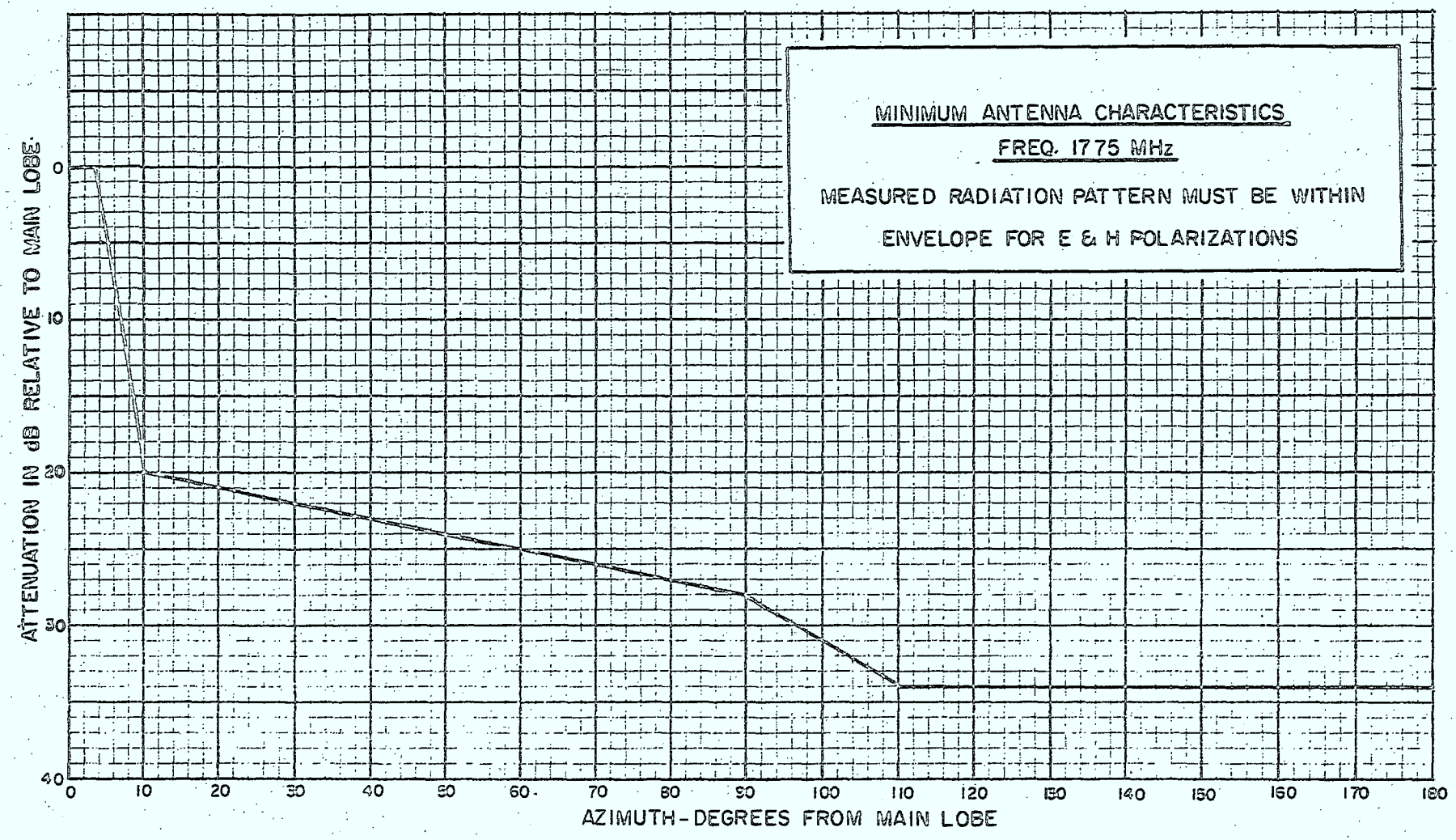
6 - 60 TELEPHONY CHANNEL SYSTEMS

FREQUENCY PAIRING FOR DUAL RF CHANNEL SYSTEMS

	GO (1st Hop)	RETURN	GO (2nd hop)	RETURN
System #1	A7-A10 V	A7'-A10' V	B7'-B10' V	B7-B10 V
System #2	A8-A11 H	A8'-A11' H	B8'-B11' H	B8-B11 H
System #3	A9-A12 V(H)	A9'-A12' V(H)	B9'-B12 V(H)	B9-B12 V(H)

Notes: This plan is repeated on the third and fourth hop with cross-polarization.

An opposite polarization scheme than that suggested above may be employed.


MINIMUM ANTENNA CHARACTERISTICS
FREQ. 1775 MHz
MEASURED RADIATION PATTERN MUST BE WITHIN
ENVELOPE FOR E & H POLARIZATIONS
ATTENUATION IN dB RELATIVE TO MAIN LOBE
0
10
20
30
40
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
AZIMUTH-DEGREES FROM MAIN LOBE

GENERAL CONSIDERATIONS

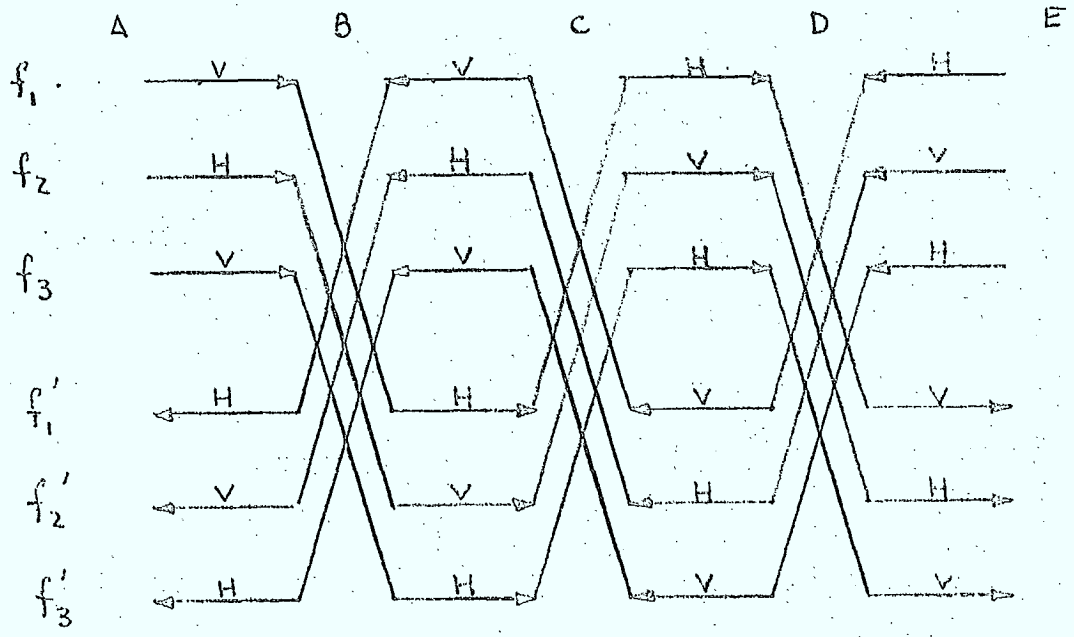
a) FREQUENCY PLANS ARE EITHER TWO FREQUENCY PLANS OR FOUR FREQUENCY PLANS (SEE PAGE 103 FOR DETAILS).

b) IN A PROPERLY DEVELOPED FREQUENCY PLAN NO STATION SHOULD TRANSMIT THE FREQUENCY IT RECEIVES. IF THIS SHOULD OCCUR SERIOUS INTERFERENCE NOISE COULD MAKE THE SYSTEM UNUSABLE . THE TRANSMITTED SIGNAL IS AT A MUCH HIGHER LEVEL THAN THE RECEIVED SIGNAL AT ANY STATION. TO AVOID INTERFERENCE FROM THE TRANSMITTER INTO THE RECEIVER, THEY MUST BE SEPARATED IN THEIR FREQUENCY.

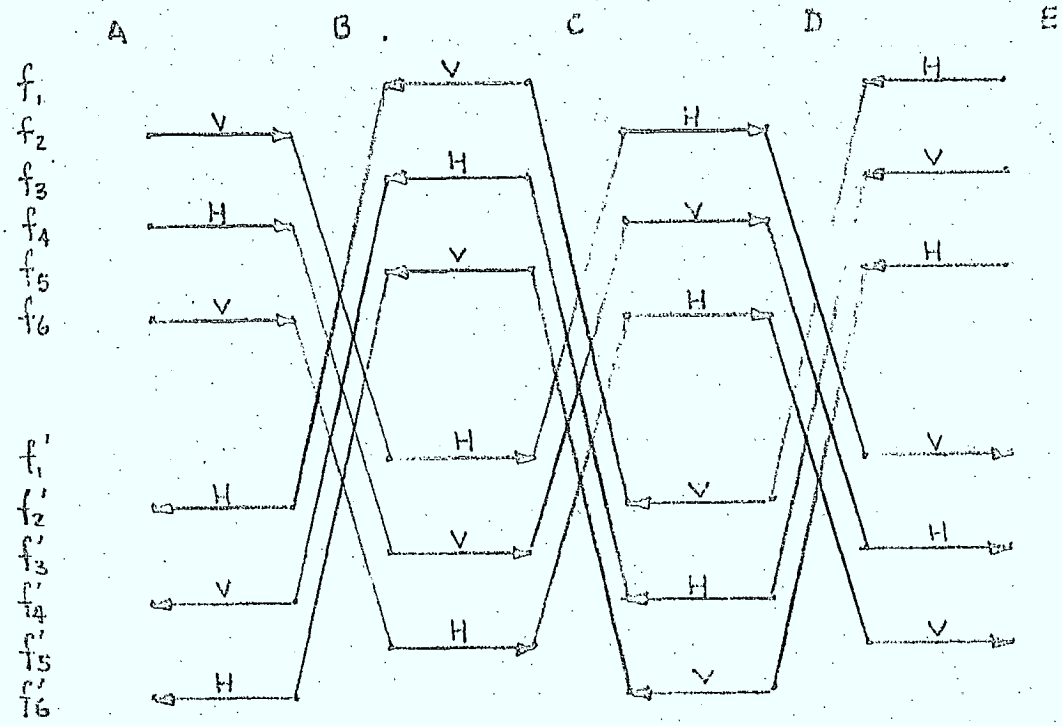
TO AVOID SUCH A HAPPENING IN A FULLY DEVELOPED PLAN ANY LOOPED SYSTEM SHOULD HAVE AN EVEN NUMBER OF HOPS.

c) THE LARGER THE SIZE OF THE ANTENNA, THE MORE IS ITS DIRECTIVITY. THIS WILL MINIMIZE THE AMOUNT OF TRANSMITTER POWER OUTSIDE THE MAIN LOBE AND CONSEQUENTLY REDUCE THE CHANCE OF INTERFERENCE IN FOREIGN SYSTEMS OPERATING AT THE SAME FREQUENCY IN THE SAME GEOGRAPHICAL AREA.

d) LOOKING AT THE FREQUENCY PLAN ON PAGE 103, TRANSMITTER A CAN CAUSE LESS INTERFERENCE IN RECEIVER C THAN IN RECEIVER D SINCE RECEIVER D OPERATES ON THE SAME FREQUENCY TRANSMITTED FROM A, WHILE C IS SEPARATED IN FREQUENCY FROM TRANSMITTER A. HENCE, IT IS RECOMMENDED TO CROSS POLARIZE FREQUENCIES FROM A TO B AND FROM C TO D TO PROVIDE MORE DISCRIMINATION.



TWO FREQUENCY PLAN



FOUR FREQUENCY PLAN

BASEBAND FREQUENCIES: -

PREVIOUSLY WE STUDIED THE PROPER ARRANGEMENT USED WHEN TRANSMITTING MICROWAVE CHANNELS AND HOW THE IF SWITCHING FUNCTIONS PROVIDE RF PROTECTION. ON PAGE 105 WE WILL FIND THE EQUIPMENT ARRANGEMENT FOR THE TRANSMITTING END BEYOND THE IF SWITCHING TILL THE OUTPUT OF THE MULTIPLEX. IN EFFECT WHAT IS SHOWN ON PAGE 105 IS THE BASEBAND PORTION OF A MICROWAVE SYSTEM'S TRANSMITTERS. THE MULTIPLEX EQUIPMENT IS USUALLY LOCATED IN THE CENTRAL OFFICE WHERE THE SWITCHING EQUIPMENT IS. THE MICROWAVE RADIO EQUIPMENT COULD BE LOCATED AT THE CENTRAL OFFICE, WHERE THE WIRE LINE ENTRANCE LINKS CABLING COULD BE A FEW FEET LONG. IN URBAN AREAS WHERE THE POSSIBILITY OF BUILDING BLOCKAGE IS PRESENT OR BECAUSE OF ZONING AND AIRPORT RESTRICTIONS, THE MICROWAVE RADIO EQUIPMENT COULD BE LOCATED A FEW MILES AWAY FROM THE CENTRAL OFFICE, IN THE OUTSKIRTS OF THE URBAN AREA.

IN THE BASEBAND HIERARCHY FOR AN FDM SYSTEM: -

12 VOICE CHANNELS (OR TELEPHONE CIRCUITS) = 1 GROUP

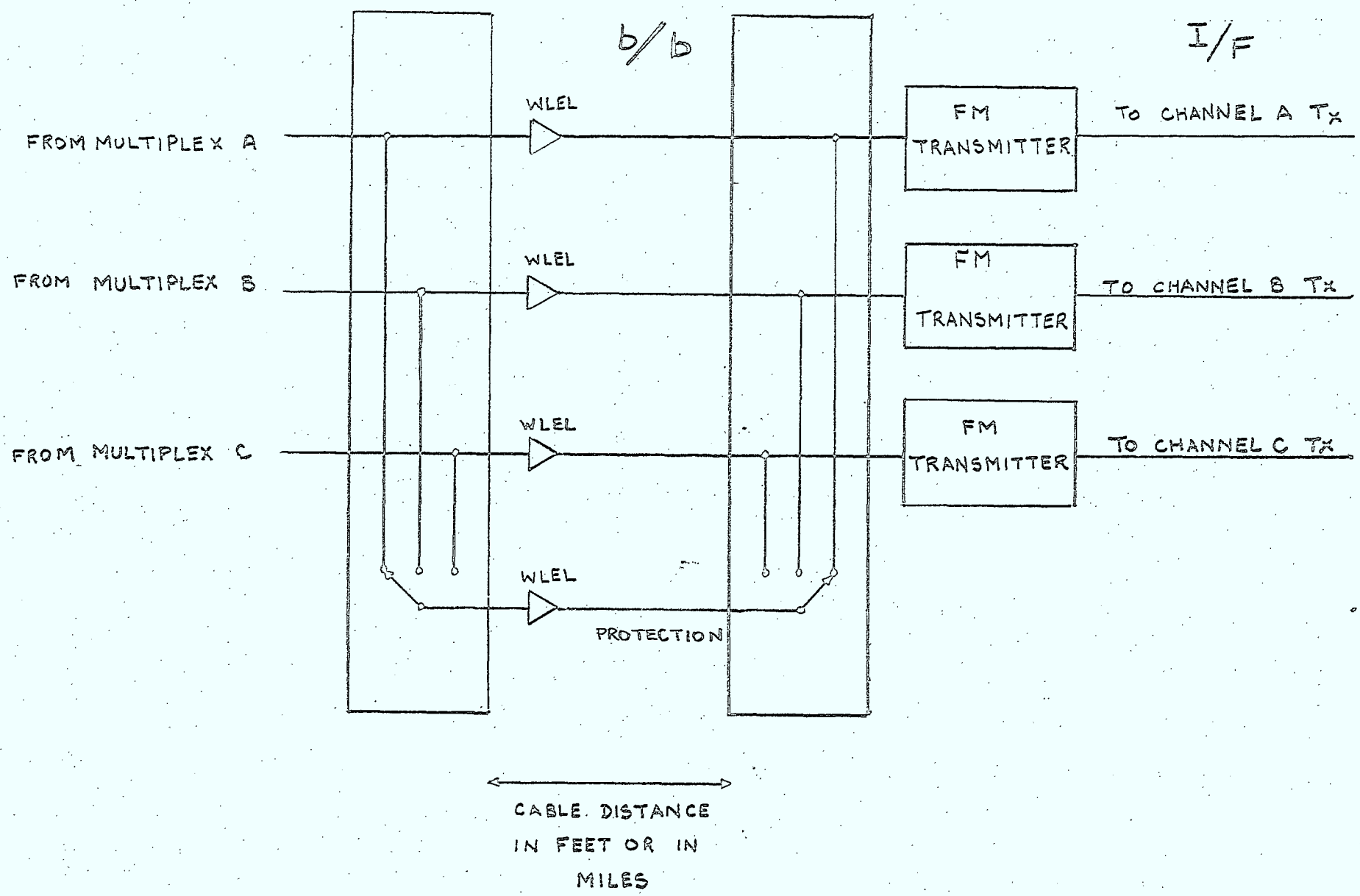
60 VOICE CHANNELS (" " ") = 5 GROUPS = 1 SUPERGROUP

600 VOICE CHANNELS (" " ") = 10 SUPERGROUPS = 1 MASTERGROUP

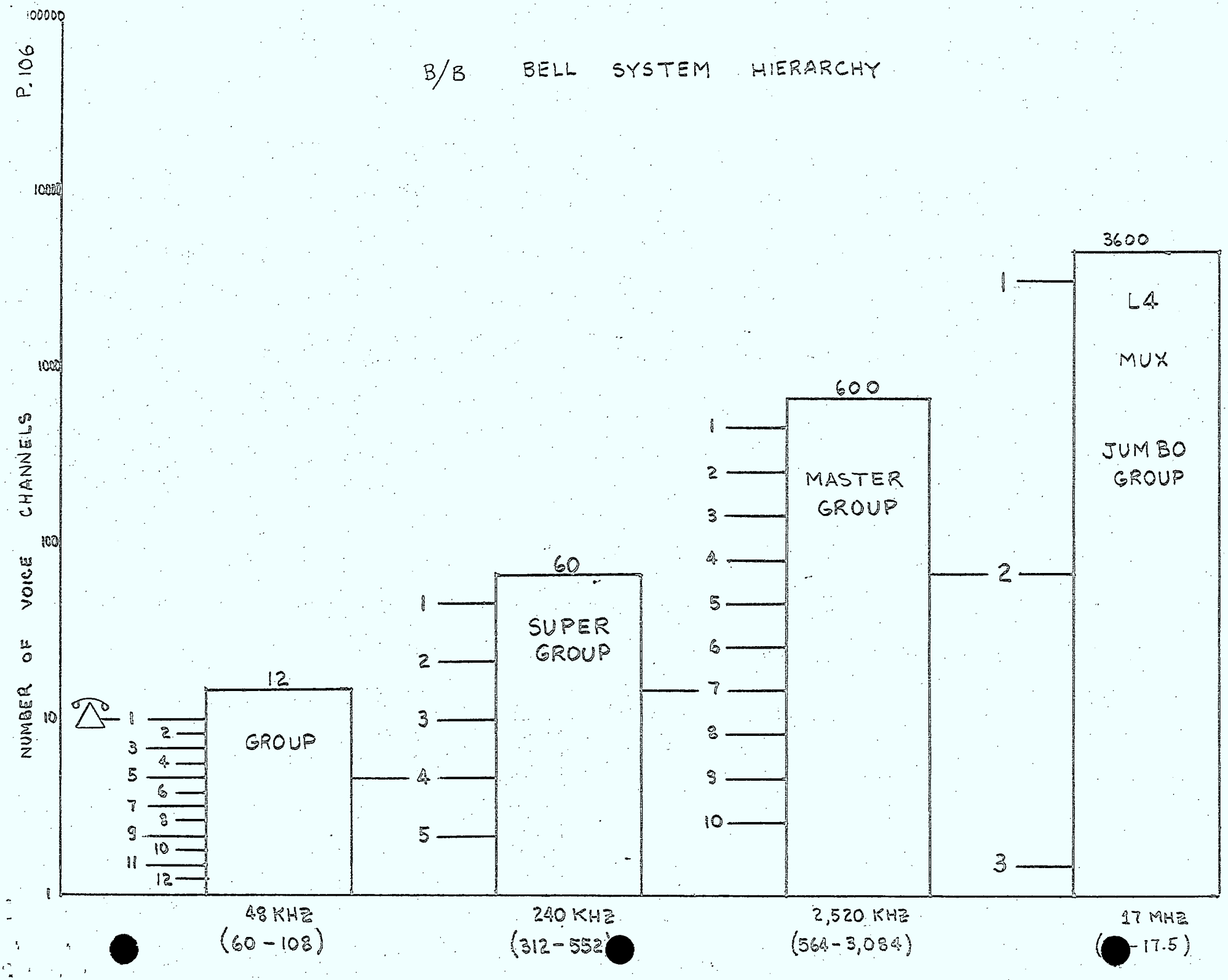
3600 VOICE CHANNELS (" " ") = 6 MASTERGROUPS = 1 JUMBOGROUP

IT SHOULD BE NOTED THAT JUMBO GROUPS ARE NOT CARRIED ON MICROWAVE FACILITIES BUT RATHER ON CABLE FACILITIES (AT&T's L4 CARRIER). THE BELL SYSTEM BASEBAND HIERARCHY IS SHOWN ON PAGE 106.

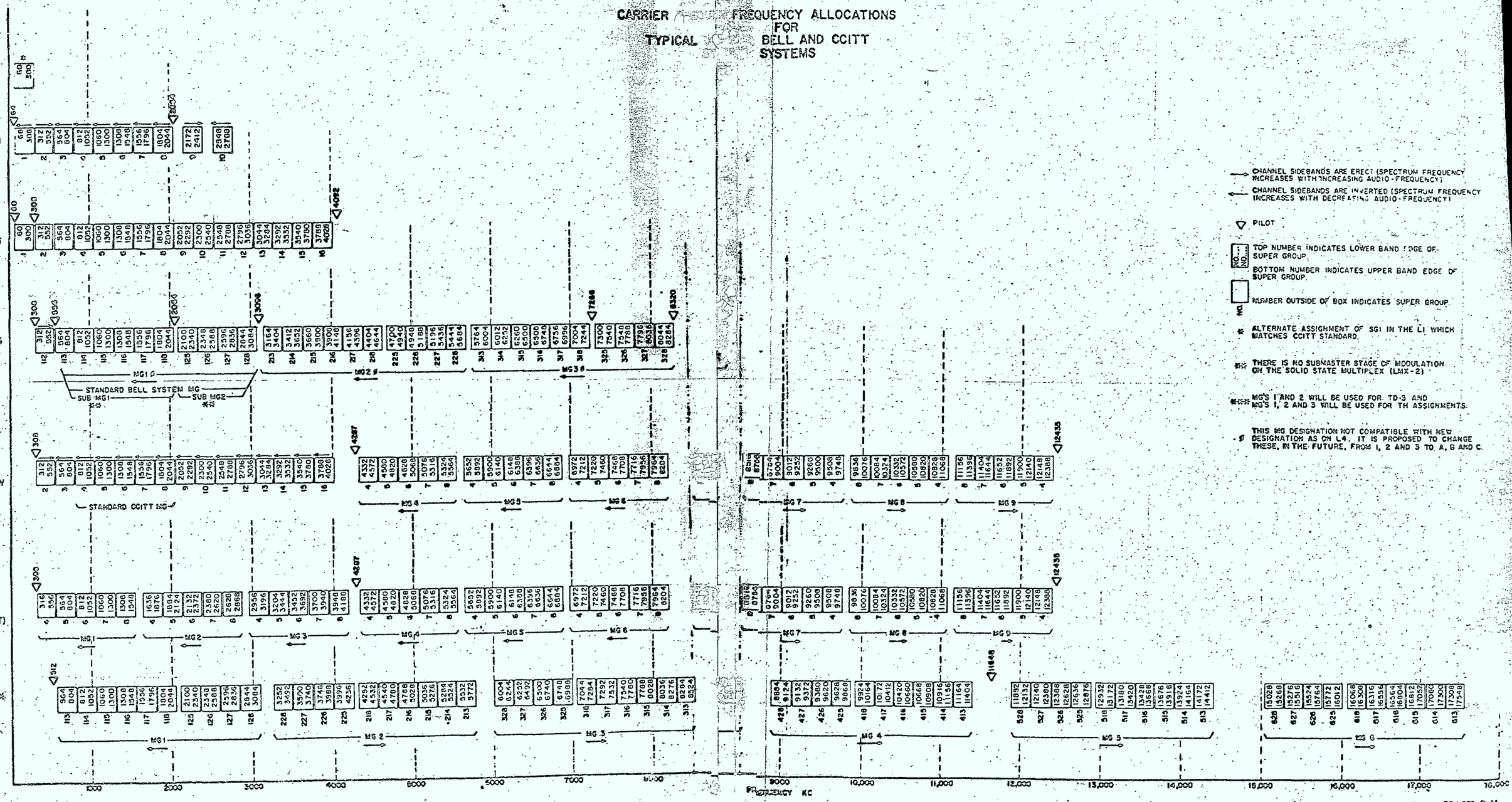
ON PAGE 107 YOU WILL FIND THE CARRIER FREQUENCY ALLOCATIONS FOR TYPICAL BELL AND CCITT SYSTEMS. THE L1 MULTIPLEX WAS THE ORIGINAL BELL SYSTEM MULTIPLEX DEVELOPED FOR THE TD-Z MICROWAVE RADIO, WITH A


b/b
I/F
FROM MULTIPLEX A
FROM MULTIPLEX B
FROM MULTIPLEX C
WLEL
WLEL
WLEL
WLEL
PROTECTION
FM TRANSMITTER
FM TRANSMITTER
FM TRANSMITTER
TO CHANNEL A Tx
TO CHANNEL B Tx
TO CHANNEL C Tx
CABLE DISTANCE IN FEET OR IN MILES

B/B BELL SYSTEM HIERARCHY



CARRIER FREQUENCY ALLOCATIONS FOR TYPICAL BELL AND CCITT SYSTEMS



CHANNEL SIDEBANDS ARE ERECT (SPECTRUM FREQUENCY INCREASES WITH INCREASING AUDIO-FREQUENCY)

CHANNEL SIDEBANDS ARE INVERTED (SPECTRUM FREQUENCY INCREASES WITH DECREASING AUDIO-FREQUENCY)

PILOT

TOP NUMBER INDICATES LOWER BAND EDGE OF SUPER GROUP.

BOTTOM NUMBER INDICATES UPPER BAND EDGE OF SUPER GROUP.

NUMBER OUTSIDE OF BOX INDICATES SUPER GROUP.

* ALTERNATE ASSIGNMENT OF SG1 IN THE L1 WHICH MATCHES CCITT STANDARD.

** THERE IS NO SUBMASTER STAGE OF MODULATION ON THE SOLID STATE MULTIPLEX (LMX-2)

*** MG'S 1 AND 2 WILL BE USED FOR TD-3 AND MG'S 1, 2 AND 3 WILL BE USED FOR TH ASSIGNMENTS.

Ø THIS MG DESIGNATION NOT COMPATIBLE WITH NEW DESIGNATION AS ON L4. IT IS PROPOSED TO CHANGE THESE, IN THE FUTURE, FROM 1, 2 AND 3 TO A, B AND C.

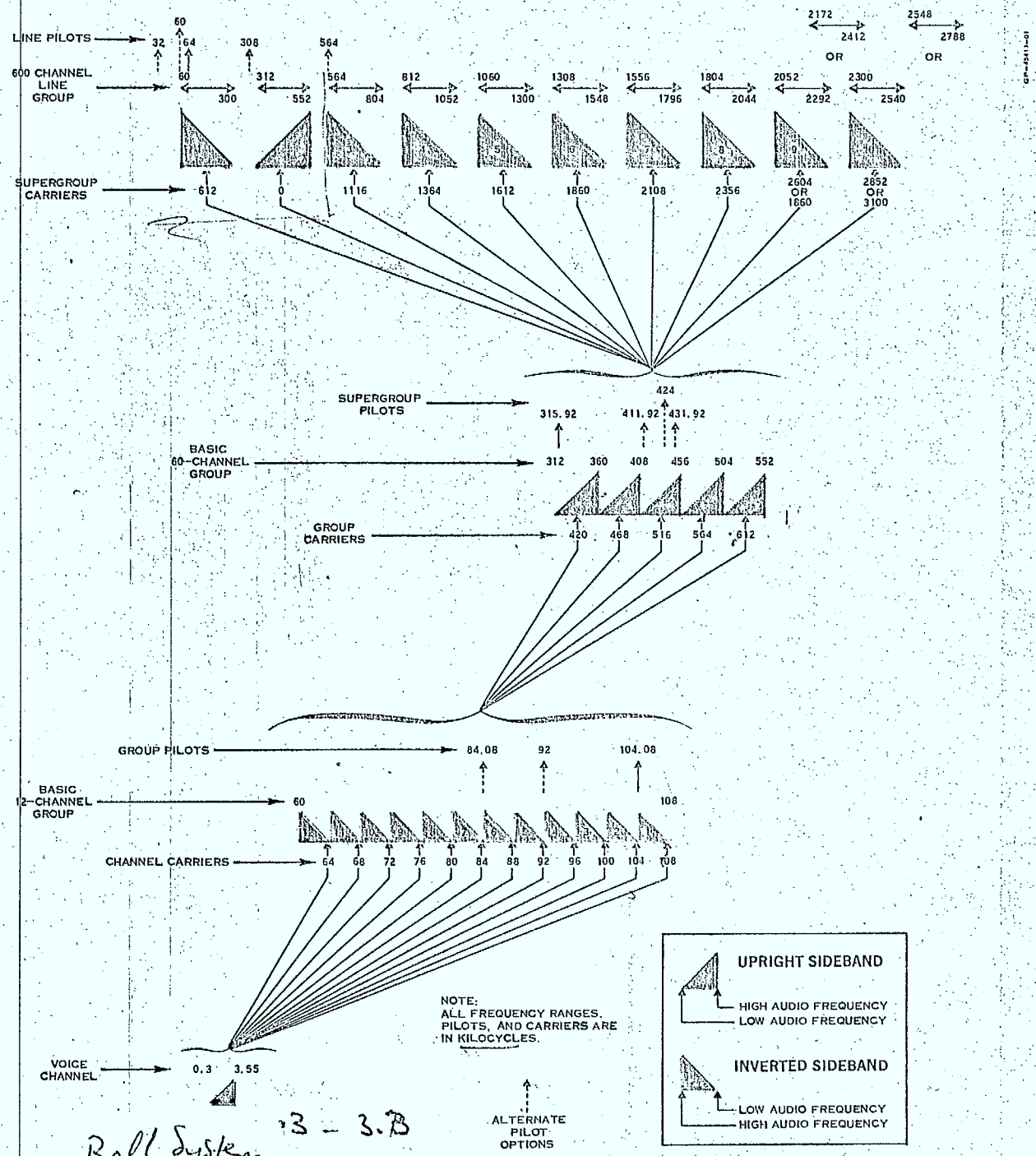
REVISED 7-65

CAPACITY OF 600 V.F. CHANNELS. THE L3 AND L4 BASEBAND FREQUENCY ALLOCATIONS ARE USED ON THE BELL SYSTEM'S L3 AND L4 CABLE CARRIERS. IT SHOULD BE NOTED, HOWEVER, THAT MASTERGROUPS 1 AND 2 ALLOCATIONS ON THE L4 SYSTEM ARE SIMILAR TO THE BASEBAND FREQUENCY ALLOCATIONS FOR THE TD-3 (BELL SYSTEM MICROWAVE SYSTEM WITH 1200 V.F. CHANNELS CAPACITY) ASSIGNMENTS.

THE CCITT 4MC SYSTEM FREQUENCY ASSIGNMENTS ARE USED FOR MICROWAVE SYSTEMS WITH A CAPACITY OF 960 V.F. CHANNELS. HIGHER CAPACITY SYSTEMS HAVE TO USE THE 12 MH_Z BASEBAND FREQUENCY ASSIGNMENTS. FOR MORE DETAILS ON THE CCITT 4MC SYSTEM SEE PAGE 109 AND 110.

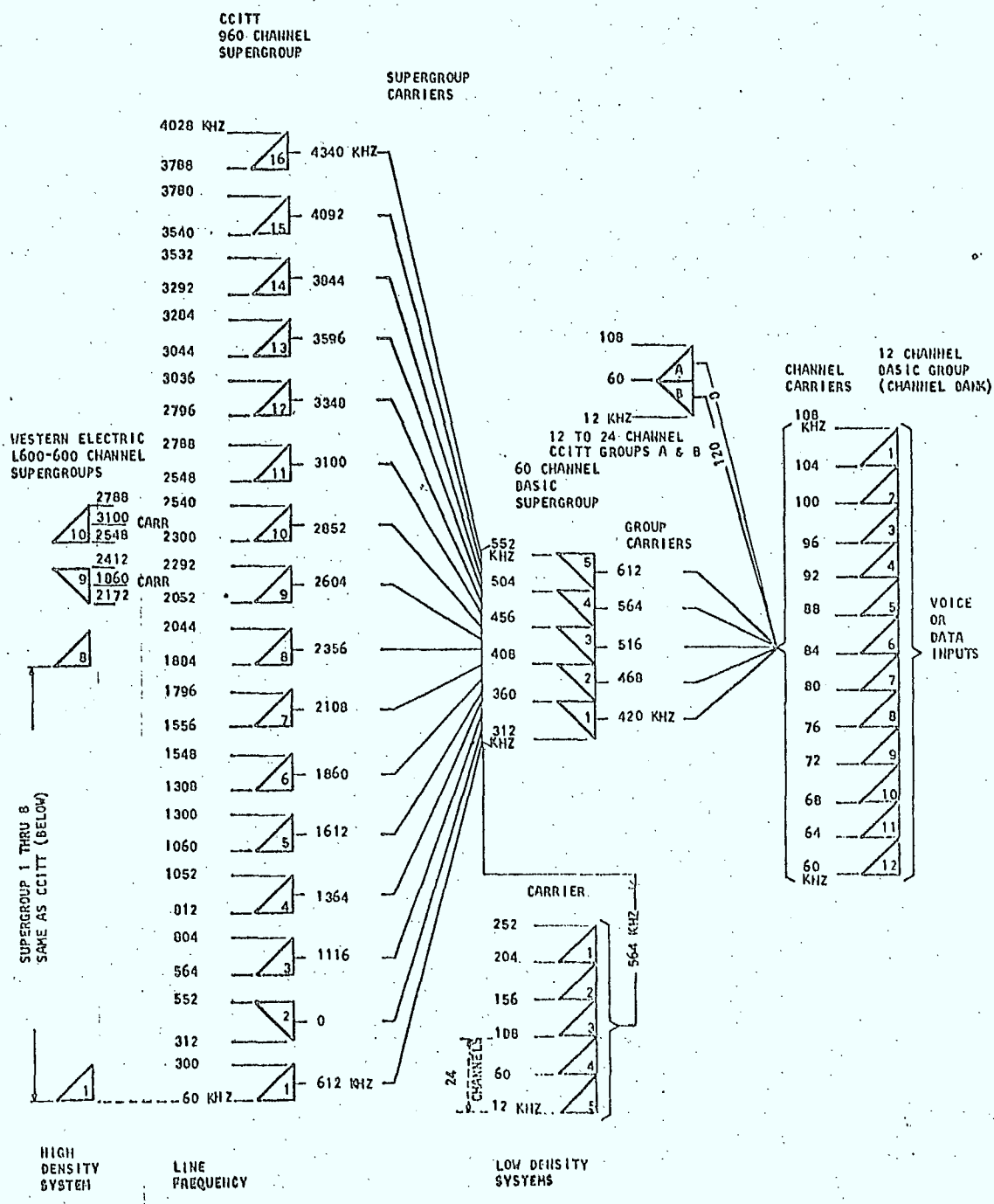
AT THIS TIME WE WILL LOOK IN DETAIL AT THE BELL SYSTEM'S 1200 CHANNEL CAPACITY BASEBAND MODULATION PLAN. THESE ARE SHOWN ON PAGES 111, 112 AND 113.

P 109

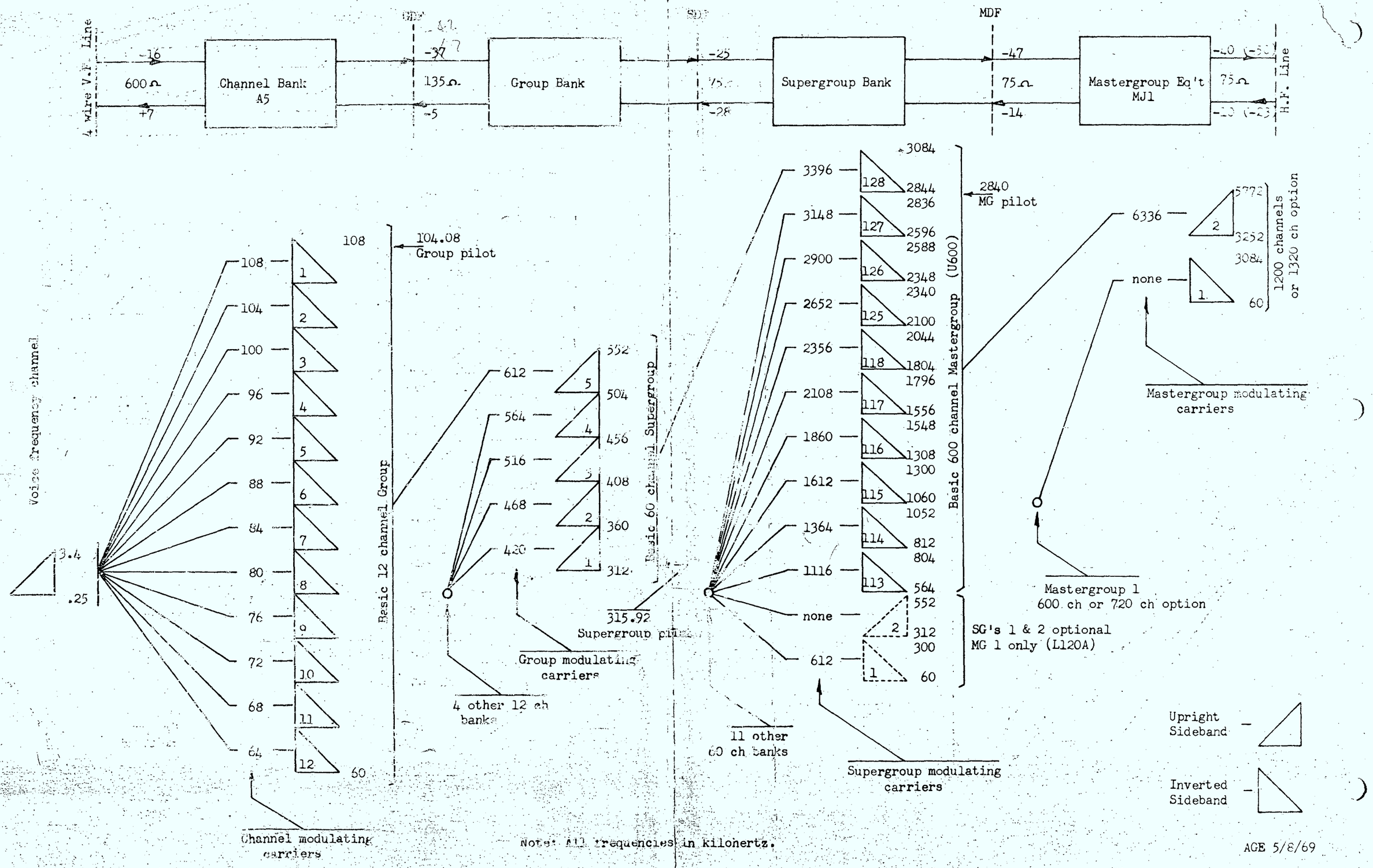


Bell System 3 - 3.B

MODULATION PLAN



MX-106 FREQUENCY ALLOCATION PLANS

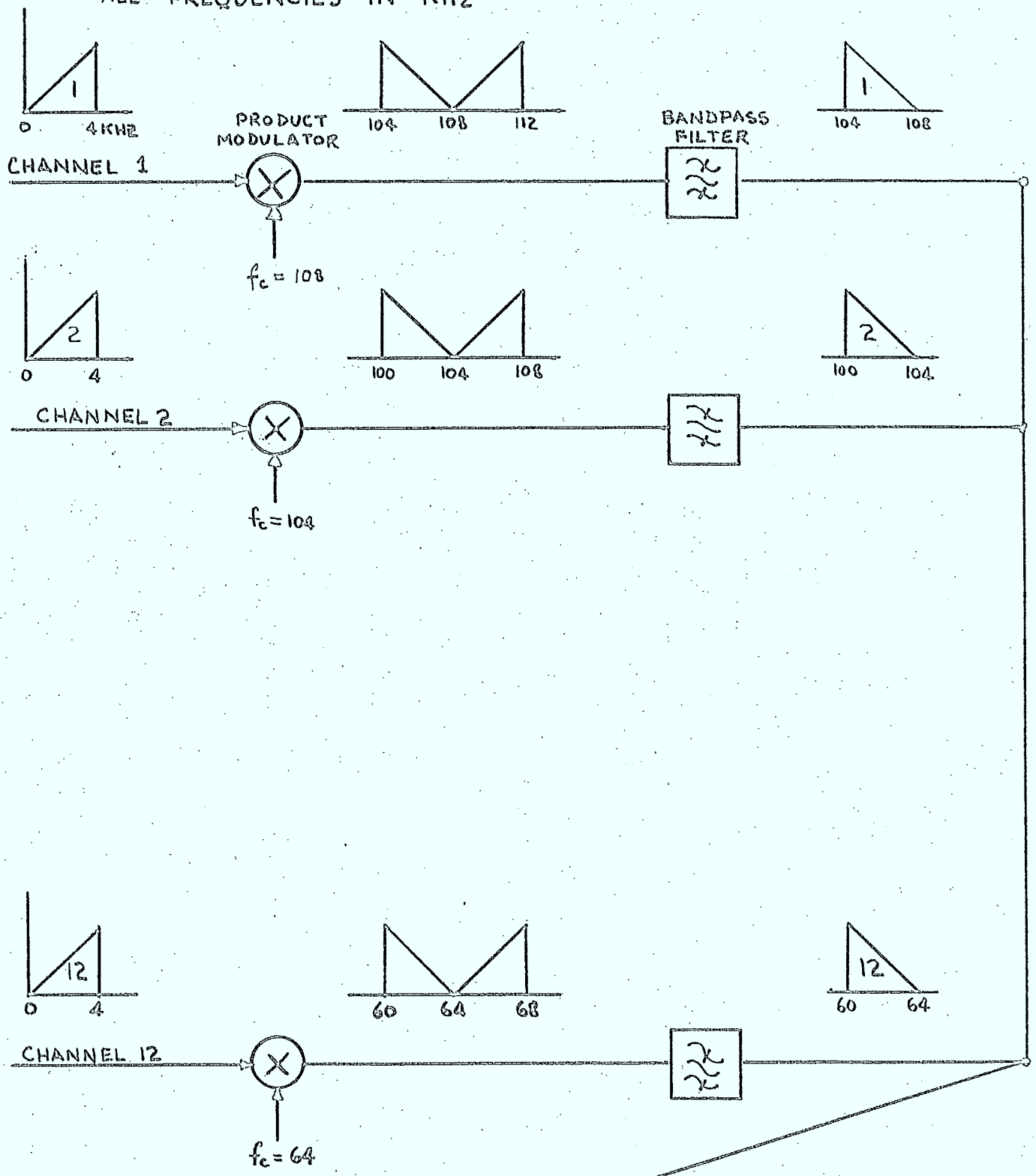


Channel modulating carriers

Notes: All frequencies in kilohertz.

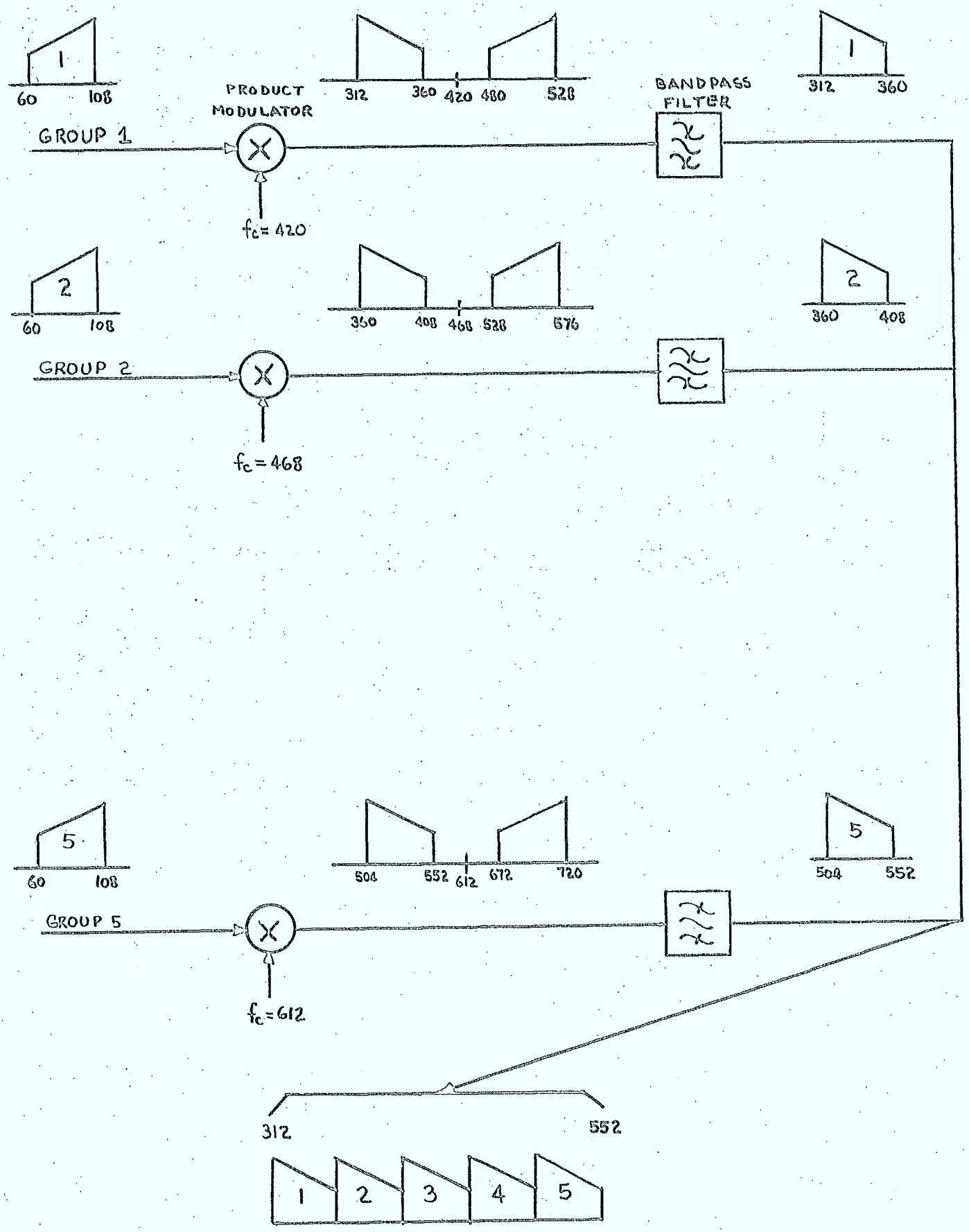
AGE 5/8/69

ALL FREQUENCIES IN KHZ



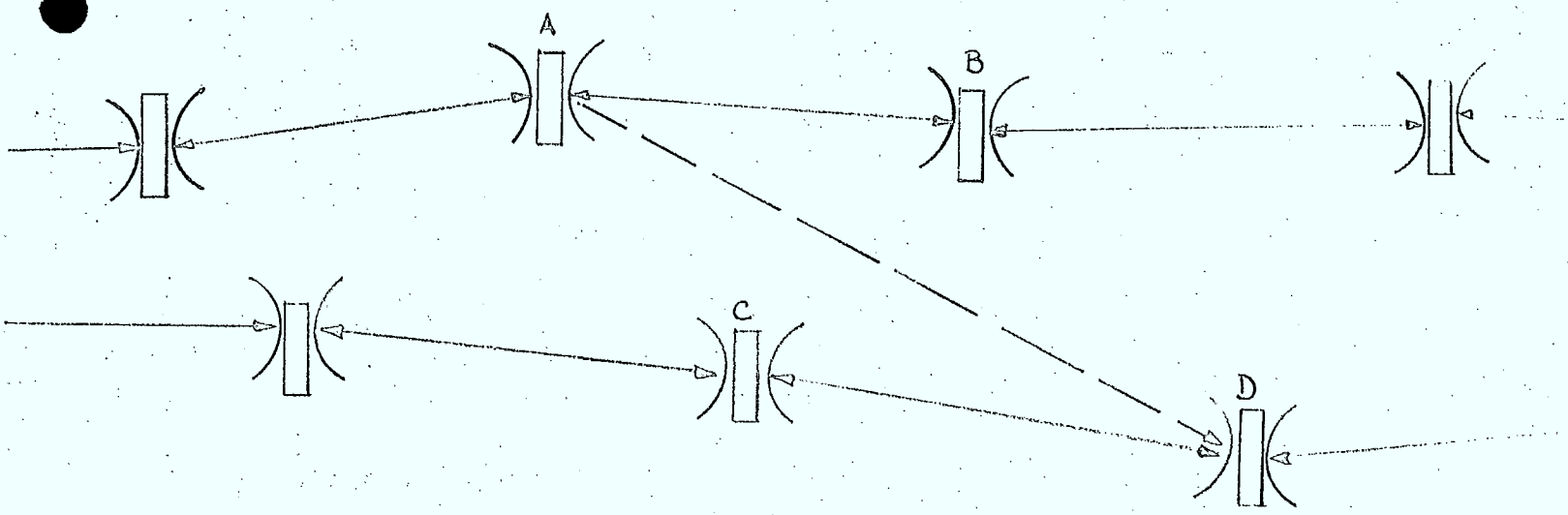
BASIC GROUP WITH A-TYPE CHANNEL BANK

ALL FREQUENCIES IN KHZ



BASIC SUPERGROUP FROM GROUP BANK

MICROWAVE INTERFERENCE: -



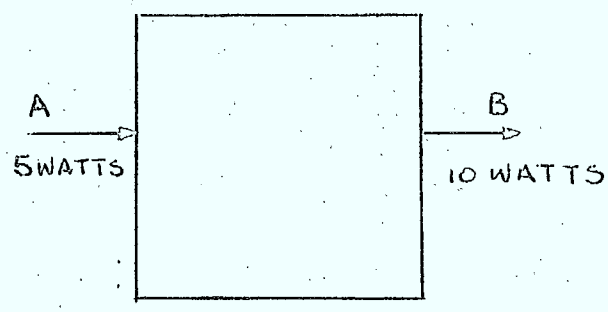
IF WE HAVE TWO MICROWAVE RADIO RELAY SYSTEMS WITH THE HOP AB ON THE FIRST SYSTEM AND CD ON THE SECOND, THE AMOUNT OF INTERFERENCE CAUSED BY TRANSMITTER A INTO RECEIVER D WILL DEPEND ON THE FOLLOWING: -

a) THE POWER OF TRANSMITTER A COMPARED TO THE POWER OF TRANSMITTER C.
b) THE DISTANCE AD COMPARED TO DISTANCE CD.
c) THE ANTENNA GAIN AND DISCRIMINATION CHARACTERISTICS AT BOTH A AND D.
d) THE FREQUENCY SEPARATION BETWEEN THE FREQUENCIES TRANSMITTED FROM A TO B AND THE FREQUENCIES RECEIVED FROM C AT D.
e) THE FILTERING CHARACTERISTICS OF THE RECEIVER AT D.
f) THE TERRAIN PROFILE CHARACTERISTICS BETWEEN SITES A & D.
g) THE CHANNEL LOADING OF HOP AB AND CD.

LET US DISCUSS BRIEFLY SOME DEFINITIONS THAT WE WILL NEED FOR THE REST OF THE COURSE.

DB

THE DECIBEL IS A UNIT FOR COMPARING THE LEVEL OF POWER BETWEEN TWO POINTS ON A CIRCUIT, PROPAGATION PATH, ETC. . .



TO COMPARE THE POWER BETWEEN INPUT POINT A AND OUTPUT POINT B WE USE THE DB UNIT.

THE DIFFERENCE IN POWER LEVEL BETWEEN THE OUTPUT AND THE INPUT IS: -

$$10 \text{ LOG } \frac{10}{5} = 10 \times .3 = 3 \text{ DB.}$$

OBVIOUSLY THE DEVICE IS AN AMPLIFIER AND ANY SIGNAL INPUTED IN IT WILL BE AMPLIFIED BY 3 DB.

DBW

INSTEAD OF COMPARING THE DIFFERENCE IN POWER LEVEL BETWEEN TWO POINTS, THIS UNIT COMPARES A CERTAIN POWER RELATIVE TO A POWER EQUAL ONE WATT.

FOR EXAMPLE A 2 WATT POWER IS EQUAL TO

$$10 \text{ LOG } \left(\frac{2 \text{ WATTS}}{1 \text{ WATT}}\right) = 10 \text{ LOG } 2 = 10 \times .3 = 3\text{DBW.}$$

$$10 \text{ WATTS IS } 10 \text{ LOG } \frac{(10 \text{ WATTS})}{(1 \text{ WATT})} = 10 \text{ LOG } 10$$

$$= 10 \times 1 = 10 \text{ DBW}$$

<u>dbm</u>

THIS UNIT COMPARES A CERTAIN POWER RELATIVE TO A POWER EQUAL TO ONE MILLIWATT.

1 WATT = 1000 MILLIWATTS

FOR EXAMPLE A HALF WATT POWER IS EQUAL TO 500 MILLIWATTS.

$$10 \text{ LOG } \frac{500 \text{ mw}}{1 \text{ mw}} = 10 \times 2.7 = 27 \text{ dbm}$$

FOR 2 WATTS, $10 \text{ LOG } \frac{2000 \text{ mw}}{1 \text{ mw}} = 10 \times 3.3 = 33$ dbm.

THE DIFFERENT POSSIBLE SAME-FREQUENCY INTERFERENCE SOURCES ARE SHOWN ON PAGE 117. OFF-FREQUENCY INTERFERENCE BETWEEN FREQUENCIES F_1 AND F_2 ARE NOT SHOWN ON THIS FIGURE.

<u>EXAMPLE</u>: -

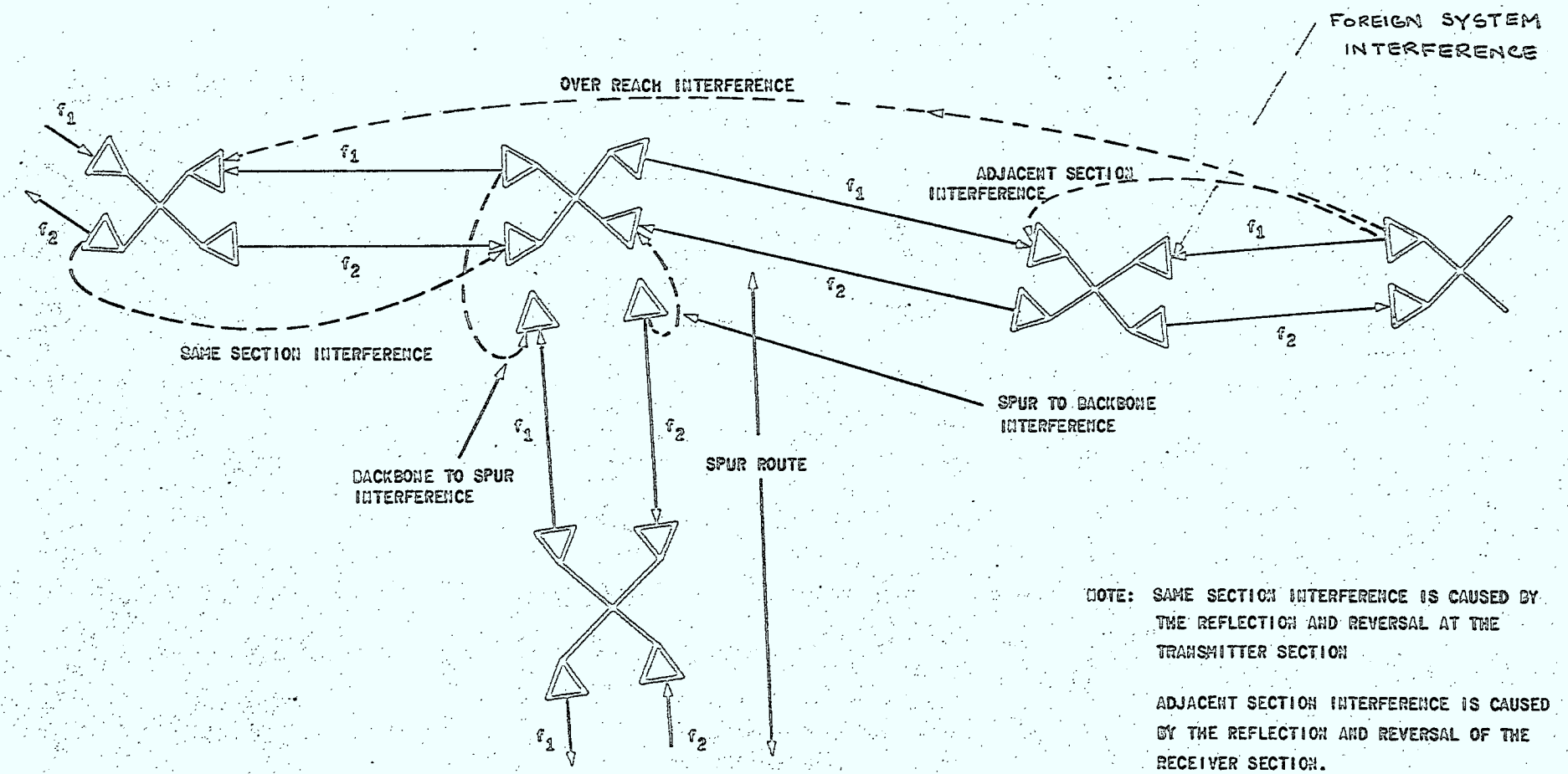
FOR THE TWO HOPS SHOWN ON PAGE 118 FIND THE TOTAL DISCRIMINATION? (THE LEVEL OF THE DESIRED CARRIER/THE INTERFERRING CARRIER).

THE TRANSMIT POWER OF STATION A = 10 LOG 5000 = 37 dbm.

THE GAIN OF THE DELAY LENS = 39.7 db.
(SEE PAGE 119)

ERP (EFFECTIVE RADIATED POWER) = TX POWER + ANTENNA GAIN

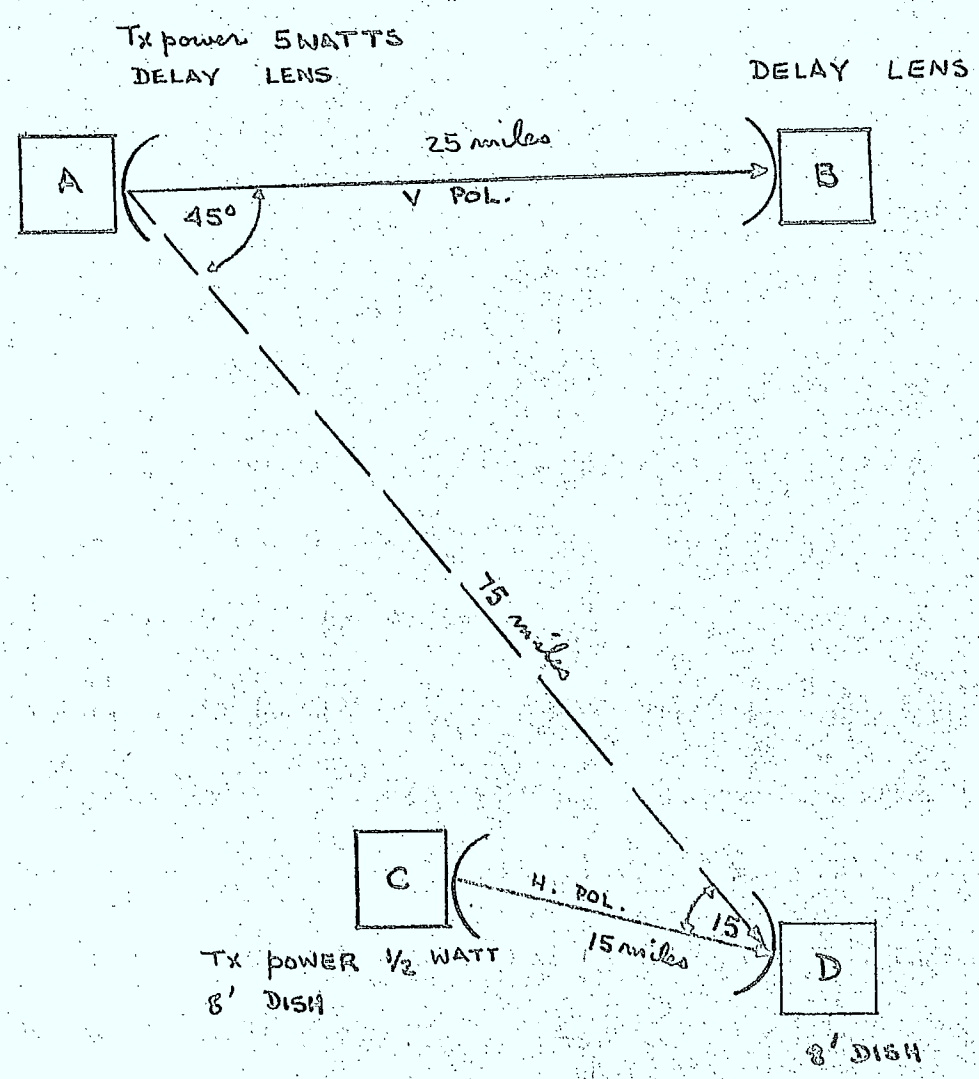
ERP AT A = 37 + 39.7 = 76.7 db.



NOTE: SAME SECTION INTERFERENCE IS CAUSED BY THE REFLECTION AND REVERSAL AT THE TRANSMITTER SECTION

ADJACENT SECTION INTERFERENCE IS CAUSED BY THE REFLECTION AND REVERSAL OF THE RECEIVER SECTION.

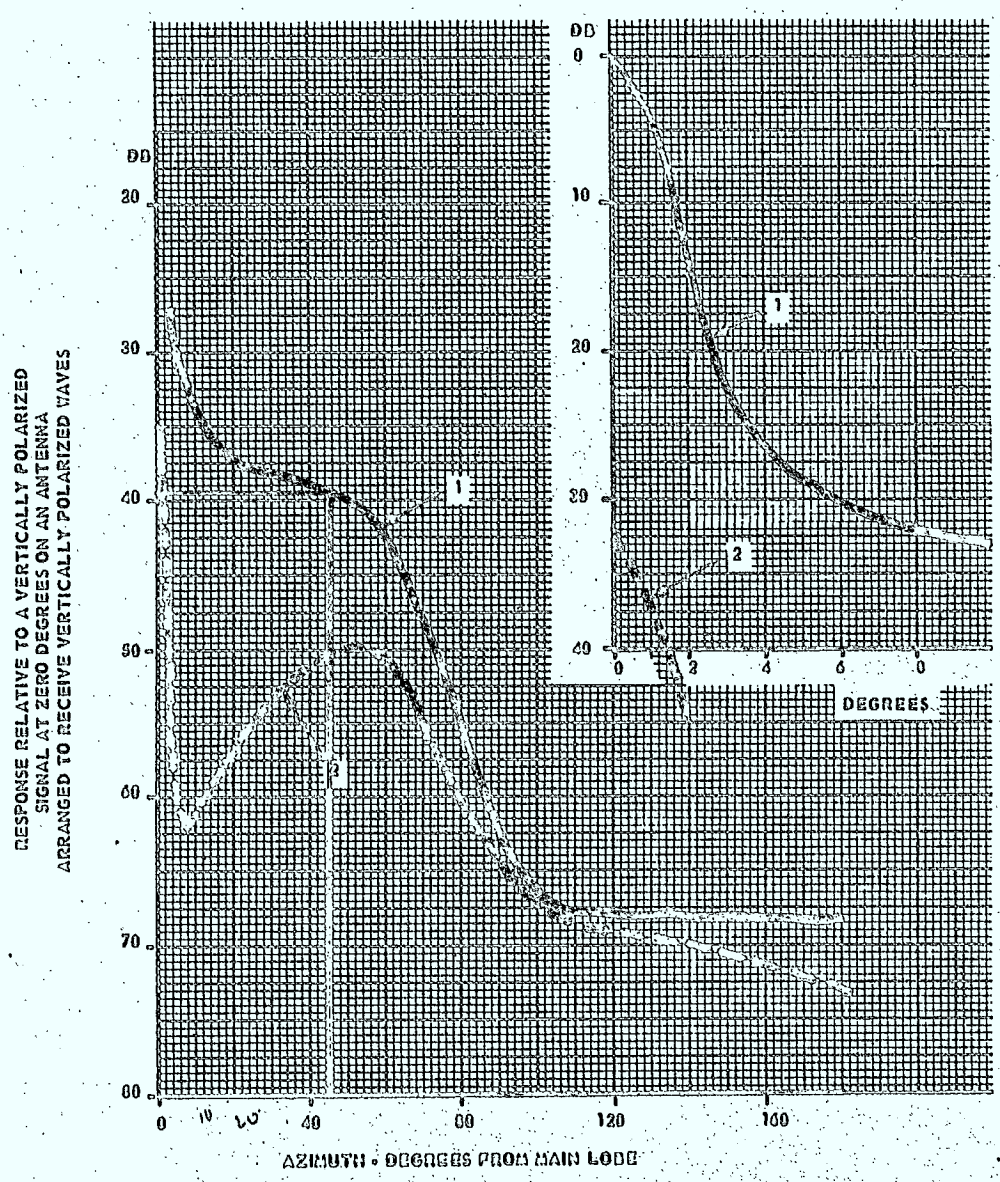
Microwave System RF Interferences


Tx power 5 WATTS
DELAY LENS
DELAY LENS
A
B
25 miles
V POL.
45°
75 miles
C
D
H. POL.
15°
15 miles
TX POWER 1/2 WATT
8' DISH
8' DISH

GAIN = 39.7 db.

POLARIZATION

ANTENNA ARRANGED TO REC	POLARIZATION OF SIGNAL	CURVE
V	V	1
H	V	2

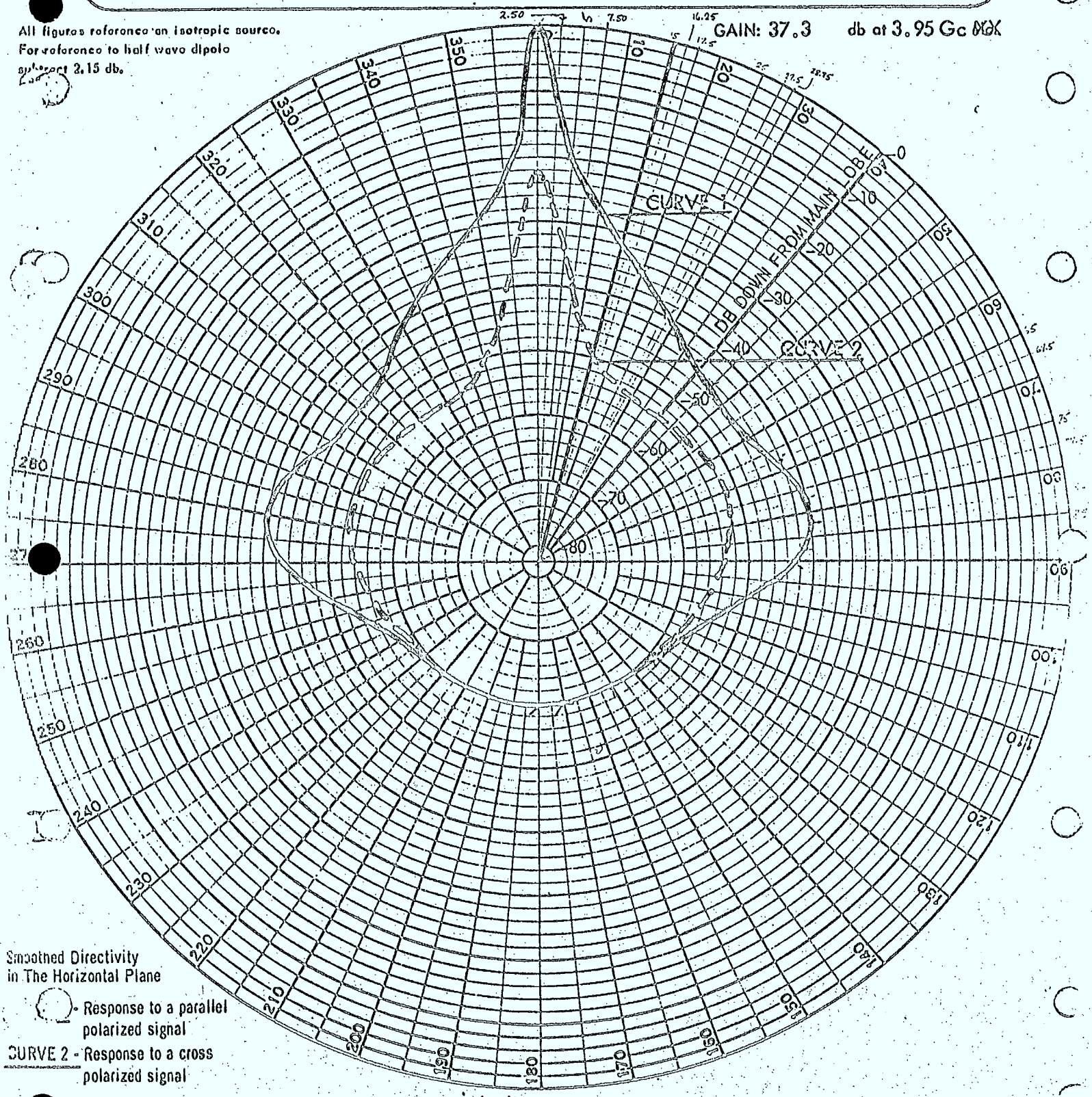


KS-5759 Delay Lens Antenna 4KMC
Directivity in the Horizontal Plane

PLANE POLARIZED, 8 FT. ANTENNA, 3.7 To 4.2 Gc
DIRECTIONAL PATTERN ENVELOPE-BOTH POLARIZATIONS

All figures reference an isotropic source.
For reference to half wave dipole subtract 2.15 db.

GAIN: 37.3 db at 3.95 Gc



Smoothed Directivity in The Horizontal Plane

- Response to a parallel polarized signal

CURVE 2 - Response to a cross polarized signal

Applies to types:
HP8-37

Andrew

P. O. BOX 807 • CHICAGO, ILLINOIS 60648 • U.S.A.
Bulletin 497 Phone 312 349-3300

New York • Washington, D. C. • Boston • Los Angeles
San Francisco • Dallas • Toronto • Montreal • Copenhagen

MS-380
Issue 1, 3/21/66

Printed in U.S.A.

THE TRANSMIT POWER OF STATION C = 10 LOG 500 = 27 dbm.

THE GAIN OF THE 8' DISH = 37.3 db. (SEE PAGE 120)

ERP AT C = 27 + 37.3 = 64.3 db.

ERP ADVANTAGE AT D = ERP AT C - ERP AT A.

= 64.3 - 76.7 = -12.4 db.

DISTANCE ADVANTAGE = 20 LOG $\frac{(75 \text{ MILES})}{(15 \text{ MILES})}$ = 20 LOG $\frac{AD}{CD}$

= 20 LOG 5 = 14 db.

ANTENNA DISCRIMINATION AT A = 39.5 db (SAME POLARIZATION)

(SEE PAGE 119)

ANTENNA DISCRIMINATION AT D = 50 db (X POLARIZATION)

ANGULAR DISCRIMINATION = 39.5 + 50 = 89.5 db.

TOTAL DISCRIMINATION =	ERP ADVANTAGE	-12.4 db
+	DISTANCE ADVANTAGE	+14
+	ANGULAR DISCRIMINATION	+89.5 db
		+ 91.1db

DESIRED CARRIER/INTERFERRING CARRIER = 91.1 db.

$\frac{C}{I}$ = 91.1 db.

SAME FREQUENCY INTERFERENCE CRITERIA

THE RATIO C/I IS RELATED TO THE NOISE IN THE BASEBAND V.F. CHANNELS. THIS RELATION IS

C/I = 88 - NOISE - RECEIVE TRANSFER CHARACTERISTIC.

NOISE IS EXPRESSED IN dbrnco, WHILE THE RTC IS EXPRESSED IN db.

THE RTC FOR DIFFERENT BELL SYSTEM OR CCIR LOADING IS GIVEN ON PAGE 123.

EXAMPLE: -

A CCIR SYSTEM WITH A LOADING OF 600 CHANNELS IS INTERFERING IN A BELL SYSTEM WITH 1800 CHANNELS LOADING. THE CALCULATED TOTAL DISCRIMINATION IS 59 db. FIND THE NOISE INTRODUCED IN EACH V.F. CHANNEL IN THE BASEBAND?

INTERFERING 600 CCIR

DESIRED 1800 BELL SYSTEM

FROM THE TABLES IN PAGE 123 RTC = 5.1 db.

C/I = 59 db

C/I = 88 - NOISE - RTC

59 = 88 - NOISE - 5.1

NOISE = 23.9 dbrnco.

FOR A PROPERLY DESIGNED SYSTEM THE NOISE CAUSED BY AN INTERFERENCE EXPOSURE SHOULD NOT EXCEED 4 dbrnco.

RECEIVER TRANSFER CHARACTERISTIC

dB

Desired	Interfering	Bell System 480	600	720	960	1200	1800	CCIR 480	600	720	960	1201	1202	1800
BELL SYSTEM	480	20.1	21.0	21.1	21.6	21.6	21.7	20.0	20.6	20.9	21.4	21.6	21.6	21.7
	600	17.2	18.8	19.2	20.4	20.7	20.9	16.9	17.8	18.5	19.7	20.3	20.6	20.8
	720	16.3	18.1	18.6	20.1	20.4	20.7	15.9	16.9	17.7	19.1	19.8	20.2	20.6
	960	11.2	13.8	14.6	17.7	18.6	19.8	10.7	12.0	13.1	15.3	16.8	18.1	19.2
	1200	9.1	11.9	12.7	16.5	17.6	19.2	8.5	9.9	11.1	13.5	15.2	16.9	18.4
	1800	4.2	7.2	8.2	12.7	14.4	17.3	3.7	5.1	6.4	9.0	11.1	13.4	15.8
CCIR	480	21.0	21.6	21.7	22.0	22.1	22.1	20.9	21.4	21.7	22.0	22.1	22.1	22.1
	600	19.7	20.7	20.9	21.5	21.6	21.7	19.5	20.2	20.6	21.2	21.5	21.6	21.7
	720	18.5	19.9	20.2	21.1	21.2	21.4	18.3	19.1	19.7	20.6	21.0	21.2	21.4
	960	15.8	17.8	18.3	20.0	20.4	20.8	15.4	16.5	17.3	18.8	19.6	20.2	20.7
	1201	13.6	15.9	16.6	19.1	19.7	20.4	13.1	14.3	15.3	17.2	18.4	19.3	20.1
	1202	10.4	13.1	13.9	17.3	18.3	19.6	9.9	11.3	12.4	14.7	16.2	17.7	19.0
	1800	7.1	10.0	10.9	15.1	16.4	18.6	6.6	8.0	9.2	11.8	13.6	15.6	17.5

THE TABLES ON PAGE 125 GIVE THE DESIRED C/I FOR DIFFERENT LOADINGS ON CCIR OR BELL SYSTEMS MICROWAVE RADIOS, ASSUMING THAT A 4 dbrnco OF NOISE COULD BE ALLOWED PER EXPOSURE.

EXAMPLE: -

FOR BELL SYSTEMS RADIO FIND THE PROPER C/I IF THE INTERFERING CHANNEL HAS 480 V.F. CHANNELS IN OPERATION WHILE THE INTERFERED CHANNEL HAS 1200 V.F. CHANNELS?

NOISE = 4 dbrnco

RTC = 9.1 db (SEE PAGE 123)

C/I = 88 - 4 - 9.1 = 74.9 db.

WHICH IS APPROXIMATELY EQUAL TO THE 76 db SHOWN ON PAGE 125.

OFF-FREQUENCY INTERFERENCE CRITERIA

THIS TYPE OF INTERFERENCE USUALLY COMES FROM FOREIGN SYSTEMS. NOISE CONTRIBUTION IS USUALLY CALCULATED FOR THE WORST CASE WHEN NEITHER CARRIERS ARE MODULATED.

PAGE 126 SHOWS THE RECOMMENDED C/I FOR OFF-FREQUENCY INTERFERENCE CASES.

EXAMPLE: -

TWO SYSTEMS HAVE 600 V.F. CHANNELS LOADING AND ARE SEPARATED BY 6 MH_Z. FIND THE RECOMMENDED C/I.

FROM PAGE 126 C/I = 55 db.

CARRIER TO INTERFERENCE RATIO

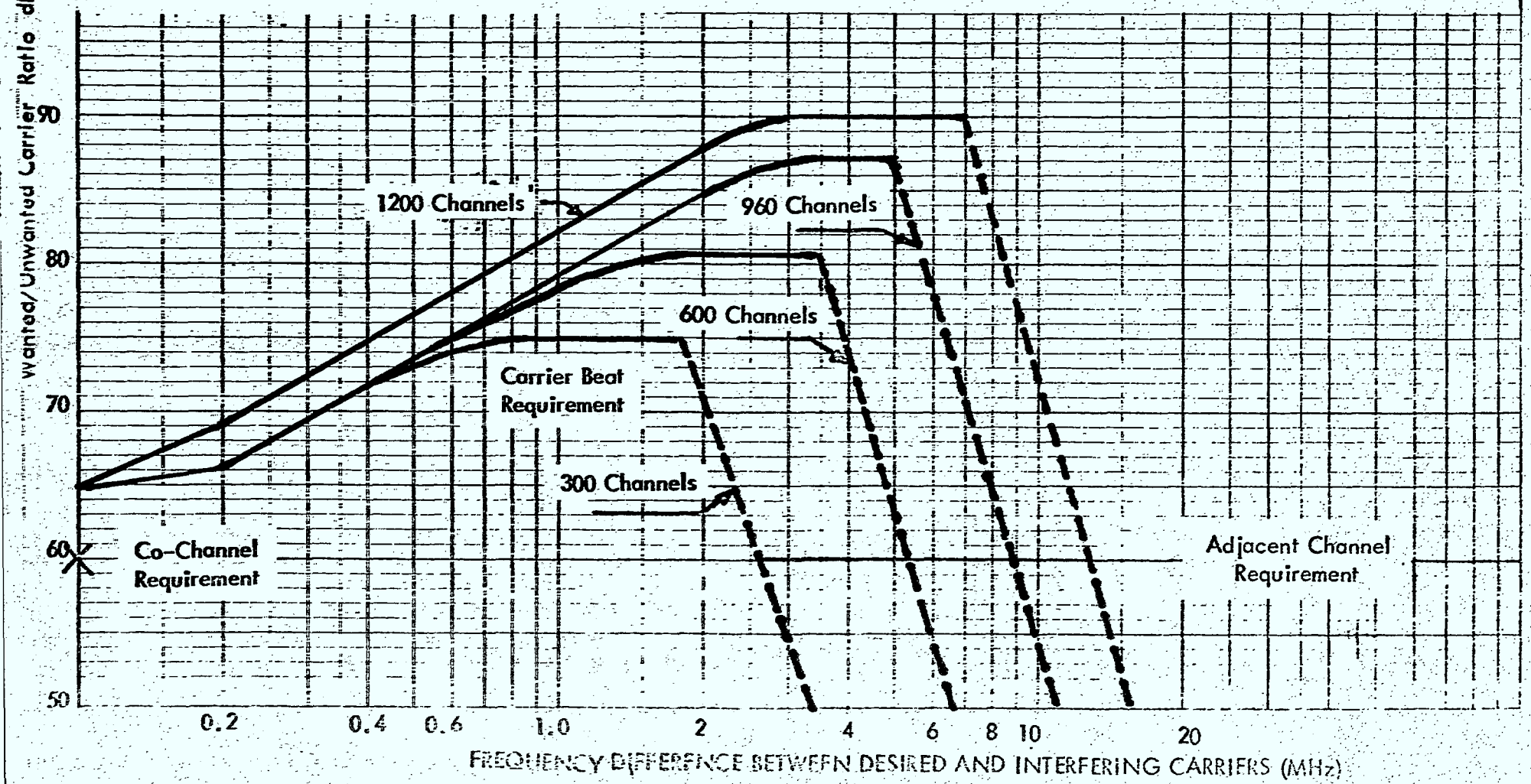
FOR 4 DBRNCO OF NOISE

db

	Interfering / Desired	Bell System 480	600	720	960	1200	1800	CCIR 480	600	720	960	1201	1202	1800
BELL SYSTEM	480	64	63	63	62	62	62	64	63	63	62	62	62	62
	600	67	65	65	64	63	63	67	66	65	64	64	64	63
	720	68	66	66	64	64	63	68	67	66	65	64	64	64
	960	73	71	70	66	65	64	74	72	71	69	68	66	65
	1200	76	73	72	68	66	65	76	75	74	71	69	67	66
	1800	81	78	77	72	70	67	81	80	79	76	74	71	69
CCIR	480	63	62	62	62	62	62	63	63	62	62	62	62	62
	600	64	63	63	63	62	62	65	64	63	63	63	62	62
	720	65	64	64	63	63	63	66	65	64	63	63	63	63
	960	68	66	66	64	64	63	69	68	67	65	65	64	63
	1201	71	68	67	65	64	64	71	70	69	67	66	65	64
	1202	74	71	70	67	66	64	74	73	72	69	68	66	65
	1800	77	74	73	69	68	65	77	76	75	72	70	68	67

ALLOWABLE INTERFERENCE LEVEL

1. Co-channel interference product limit: 10 pW FIA for each interference source.
2. Spurious level is −65 dBmO or smaller for an unmodulated interference signal.
3. Adjacent channel results in crosstalk lower than basic noise under any propagation conditions.
4. Effect of CCIR pre-emphasis included.
5. Deviation is 200 kHz RMS for 300, 600 and 960 channels and is 140 kHz RMS for 1200 channels.



SATELLITE INTERFERENCE CRITERIA

COMMUNICATIONS SATELLITE SYSTEMS OPERATE IN BOTH THE 4 GH_Z AND 6 GH_Z FREQUENCY BANDS. GEOSTATIONARY SATELLITES ARE POSITIONED 22,000 MILES OVER THE EQUATOR (0 DEGREES OF LATITUDE), AND ROTATE AT A SPEED EQUAL TO THAT OF THE EARTH. THE LONGITUDE OF THE SATELLITE COULD VARY WHILE THE LATITUDE IS ALWAYS AT 0 DEGREES.

THE UPWARD LINK IS IN THE 6 GH_Z BAND, WHILE THE DOWNWARD LINK IS IN THE 4 GH_Z BAND. THIS MEANS THAT TERRESTIAL SYSTEMS OPERATING IN THE 6 GH_Z BAND COULD INTERFERE WITH THE SIGNAL RECEIVED AT THE SATELLITE, WHILE THE SATELLITE INTERFERES WITH TERRESTIAL SYSTEMS OPERATING IN THE 4 GH_Z BAND.

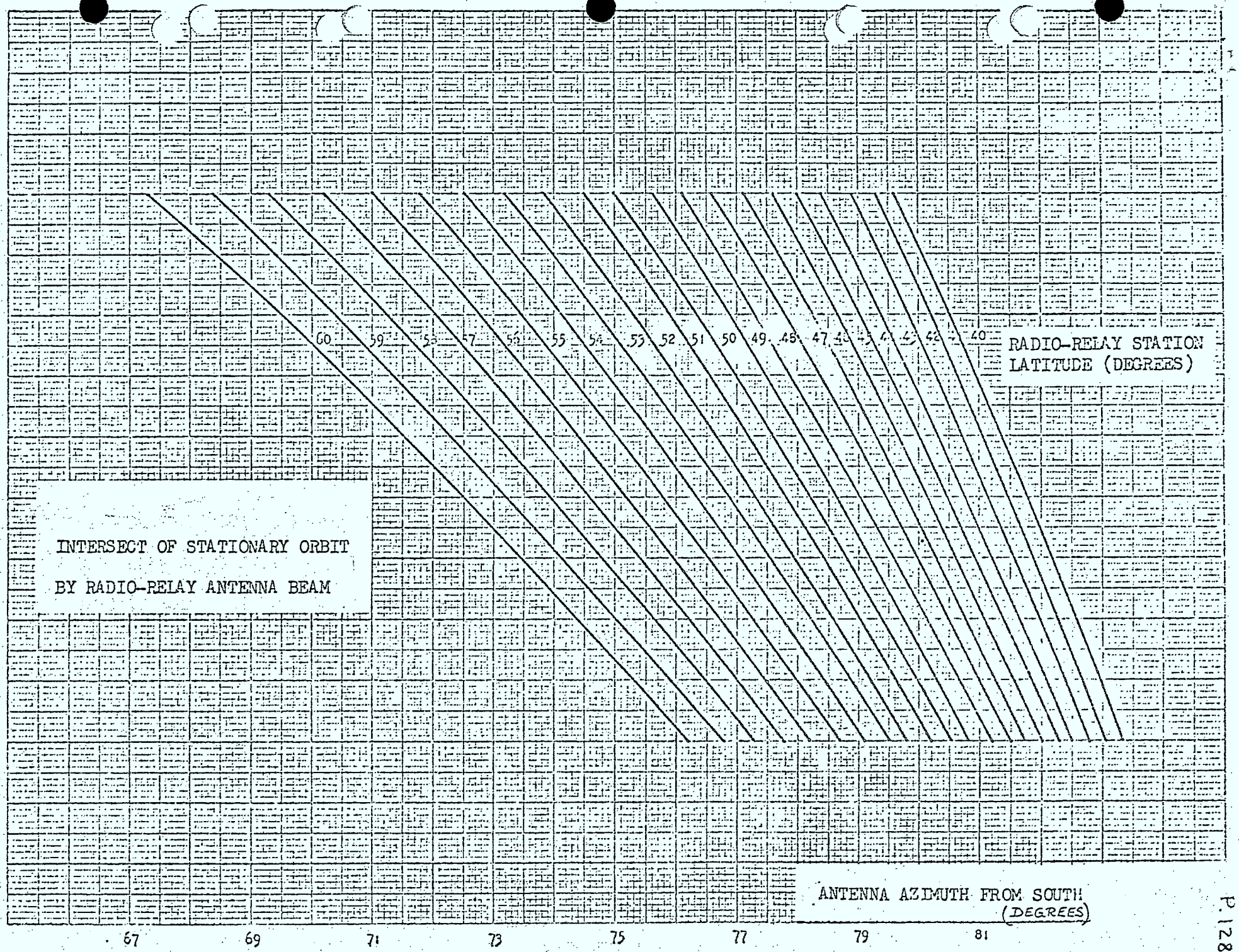
EXAMPLE:

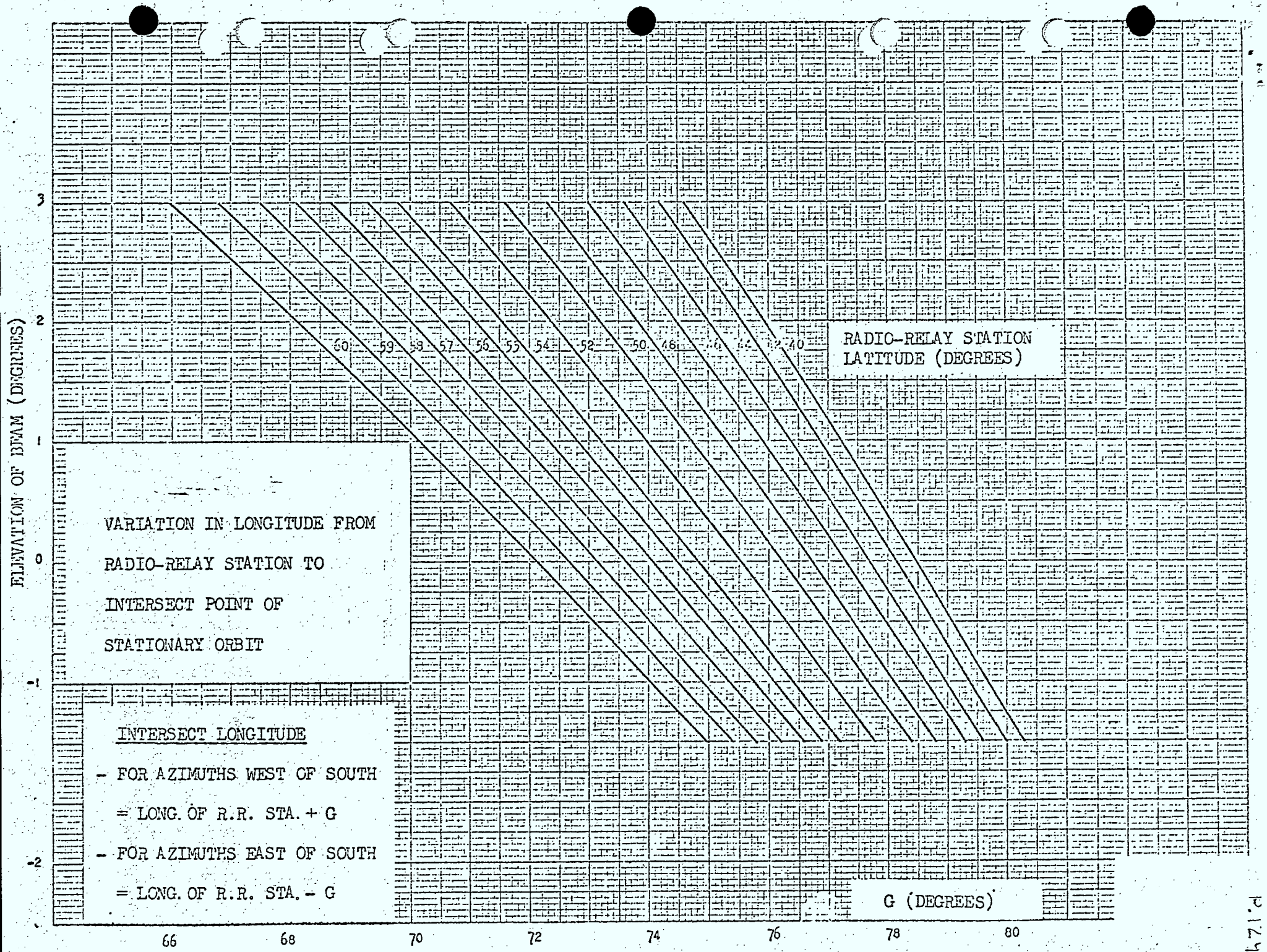
A TERRESTIAL MICROWAVE SYSTEM OPERATING IN THE 4 GH_Z BAND HAS A RECEIVER WITH A LATITUDE OF 48 DEGREES AND AN ELEVATION ANGLE OF + 0.5 DEGREE. ITS AZIMUTH FROM SOUTH TO EAST IS 78°. FIND THE INTERSECT ANGLE OF THE STATIONARY ORBIT BY THE RADIO-RELAY ANTENNA BEAM. IN ADDITION, FIND THE LONGITUDE OF THE INTERSECT POINT OF THE STATIONARY ORBIT.

FROM THE GRAPH ON PAGE 128

WITH AN ELEVATION ANGLE OF + .5 DEGREE

AND A LATITUDE = 48 DEGREES


INTERSECT OF STATIONARY ORBIT
BY RADIO-RELAY ANTENNA BEAM
RADIO-RELAY STATION
LATITUDE (DEGREES)
60
59
57
55
53
52
51
50
49
47
40
ELEVATION OF BEAM (DEGREES)
3
2
1
0
-1
-2
ANTENNA AZIMUTH FROM SOUTH
(DEGREES)
67
69
71
73
75
77
79
81


ELEVATION OF BEAM (DEGREES)
3
2
1
0
-1
-2
60
59
58
57
56
55
54
52
50
48
46
44
42
40
RADIO-RELAY STATION LATITUDE (DEGREES)
VARIATION IN LONGITUDE FROM RADIO-RELAY STATION TO INTERSECT POINT OF STATIONARY ORBIT
INTERSECT LONGITUDE
- FOR AZIMUTHS WEST OF SOUTH = LONG. OF R.R. STA. + G
- FOR AZIMUTHS EAST OF SOUTH = LONG. OF R.R. STA. - G
G (DEGREES)
66
68
70
72
74
76
78
80

P.174

THE ANTENNA AZIMUTH FROM SOUTH FOR A DIRECT INTERSECT OF STATIONARY ORBIT IS 79 DEGREES.

THE DIFFERENCE IN THE INTERSECT ANGLE IS 79-78 = ONE DEGREE. IT IS RECOMMENDED THAT THE DIFFERENCE IN THE INTERSECT ANGLE BE MORE THAN FOUR DEGREES AND NOT LESS THAN TWO DEGREES.

IF THE LONGITUDE OF THE MICROWAVE RECEIVER IS X THEN THE LONGITUDE OF THE INTERSECT POINT OF THE STATIONARY ORBIT IS: -

(X - 76) DEGREES (SEE PAGE 129).

WE WILL DEAL IN THIS PORTION OF THE COURSE WITH THE NOISE PERFORMANCE OF A MICROWAVE SYSTEM.

THERE ARE BASICALLY TWO TYPES OF NOISES IN A TRANSMISSION SYSTEM.

a) IMPULSE NOISE: - WHICH IS OF TEN THE NOISE PRODUCED BY EXTERNAL SOURCES TO THE SYSTEM ITSELF. THIS TYPE OF NOISE IS HARD TO PREDICT AND IS MEASURED FOR A CERTAIN DURATION OF TIME, SINCE AS THE NAME INDICATES IT, THE IMPULSE NOISE IS NOISE PRODUCED DURING A SHORT DURATION OF TIME.

IMPULSE NOISE COULD BE PRODUCED BY HIGH VOLTAGE SWITCHES AND HAS A VERY MARKED EFFECT ON DATA TRANSMISSION.

b) STEADY STATE NOISE: - THIS TYPE OF NOISE IS INHERENT TO THE SYSTEM ITSELF AND PRODUCED INTERNALLY, AND COULD BE PREDICTED BY CALCULATIONS.

THE STEADY STATE NOISE INCLUDES: -

1. THERMAL NOISE: - THIS NOISE IS INDEPENDENT ON SYSTEM LOADING, HOWEVER, BECAUSE OF THE PROPAGATION CHARACTERISTICS OF MICROWAVE PATHS, IT WILL BE A FUNCTION OF THE FADING ON THESE PATHS. FADES DUE TO PROPAGATION ARE TIME DEPENDENT AND COULD BE EXPRESSED STATISTICALLY RELATIVE TO LONG PERIODS OF TIME (e.g., ONE MONTH).

2. INTERMODULATION NOISE: - THIS NOISE IS DEPENDENT ON SYSTEM LOADING, HENCE IS TIME DEPENDENT DUE TO VARYING TRAFFIC CONDITIONS. HENCE, MAXIMUM INTERMODULATION NOISE COULD BE EXPRESSED IN TERMS OF "BUSY HOUR".

THE MOST PROMINENT SOURCES OF THERMAL NOISE ARE THE:

1. BASEBAND AND MODULATING EQUIPMENT
2. LOCAL OSCILLATORS
3. R.F. AMPLIFIERS
4. RECEIVER "FRONT END"

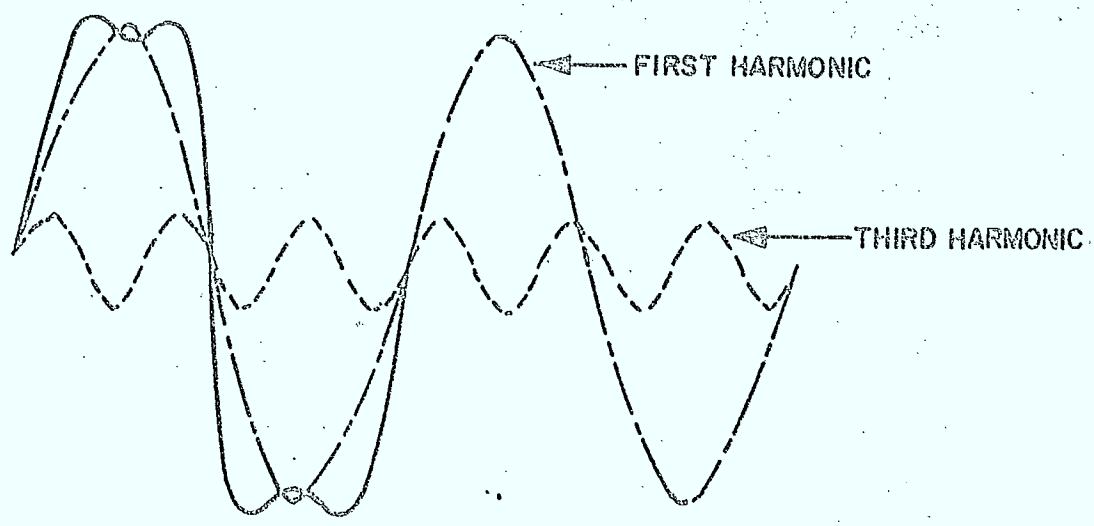
THE MOST PROMINENT SOURCES OF INTERMODULATION NOISE ARE THE:

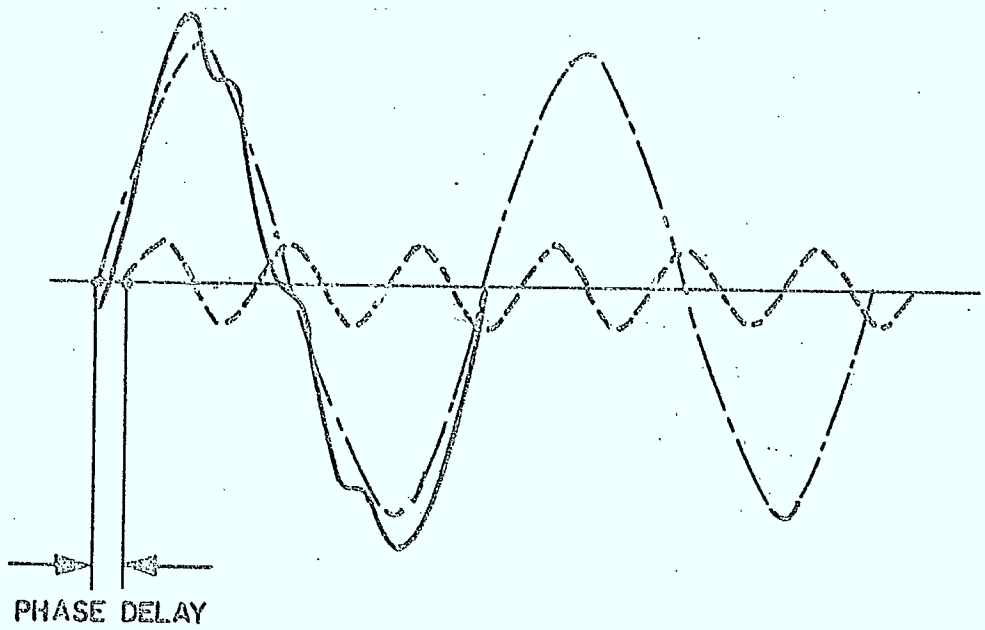
1. PHASE CHARACTERISTICS OF RF AND IF CIRCUITS
2. AMPLITUDE CHARACTERISTICS OR RF AND IF CIRCUITS
3. AMPLITUDE - LINEORITY CHARACTERISTICS OF THE BASEBAND EQUIPMENT
4. ECHOES

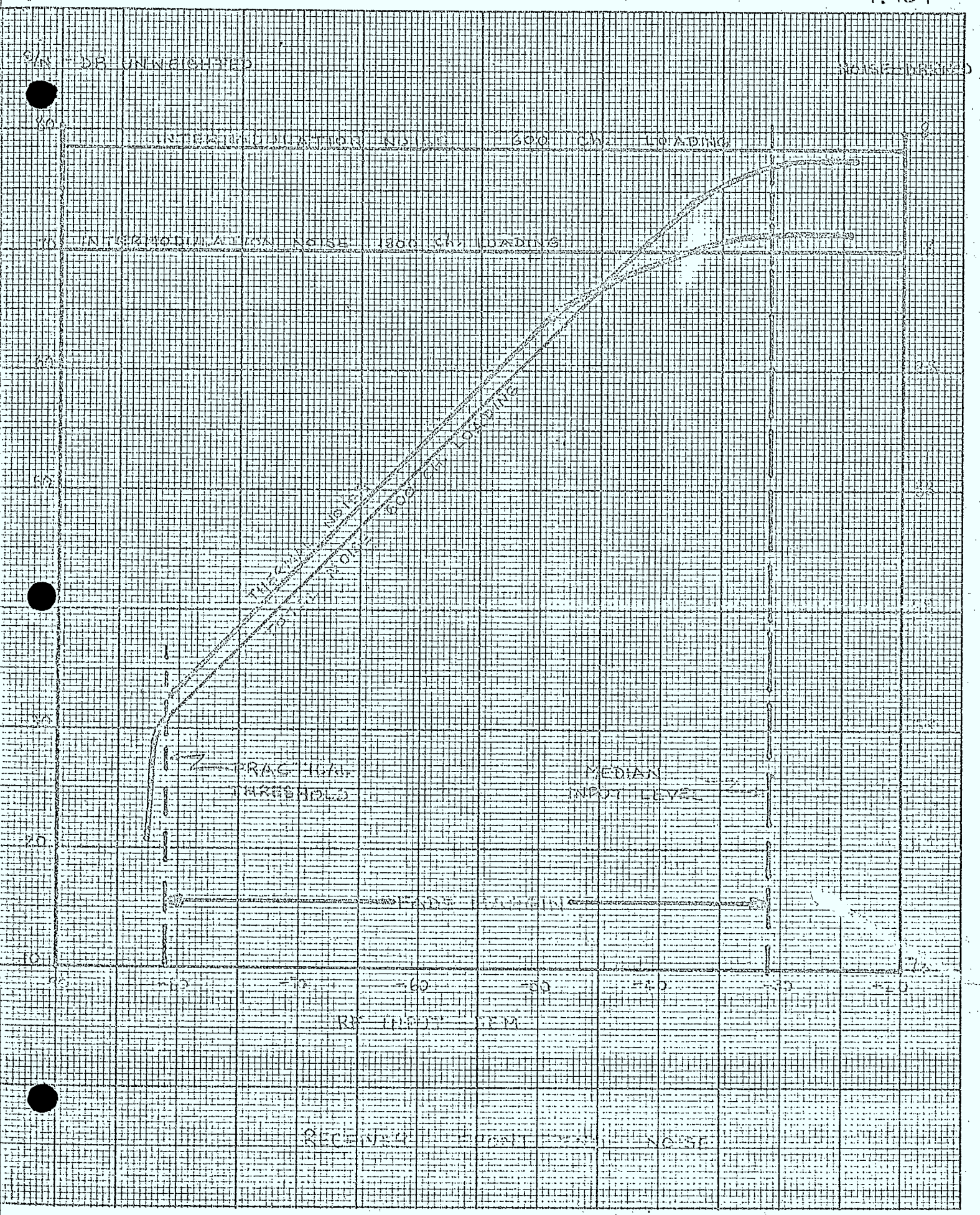
THE EFFECT OF PHASE DISTORTION IS SHOWN ON PAGE 133. A SINE WAVE, WHICH REPRESENTS THE SIGNAL IN THIS CASE, IS COMPOSED OF MANY HARMONICS, WHICH HAVE DIFFERENT FREQUENCIES. IF A CIRCUIT PASSES DIFFERENT FREQUENCIES AT DIFFERENT SPEEDS, THAN THE HIGHER HARMONICS WILL ARRIVE AT A CERTAIN POINT IN THE CIRCUIT LATER OR BEFORE THE LOWER HARMONICS, WHICH CAUSES THE PHASE DISTORTION.

ON PAGE 134 AND 135 THE THERMAL AND INTERMODULATION NOISE IS SHOWN FOR THE R.F. PORTION OF A MICROWAVE RECEIVER.

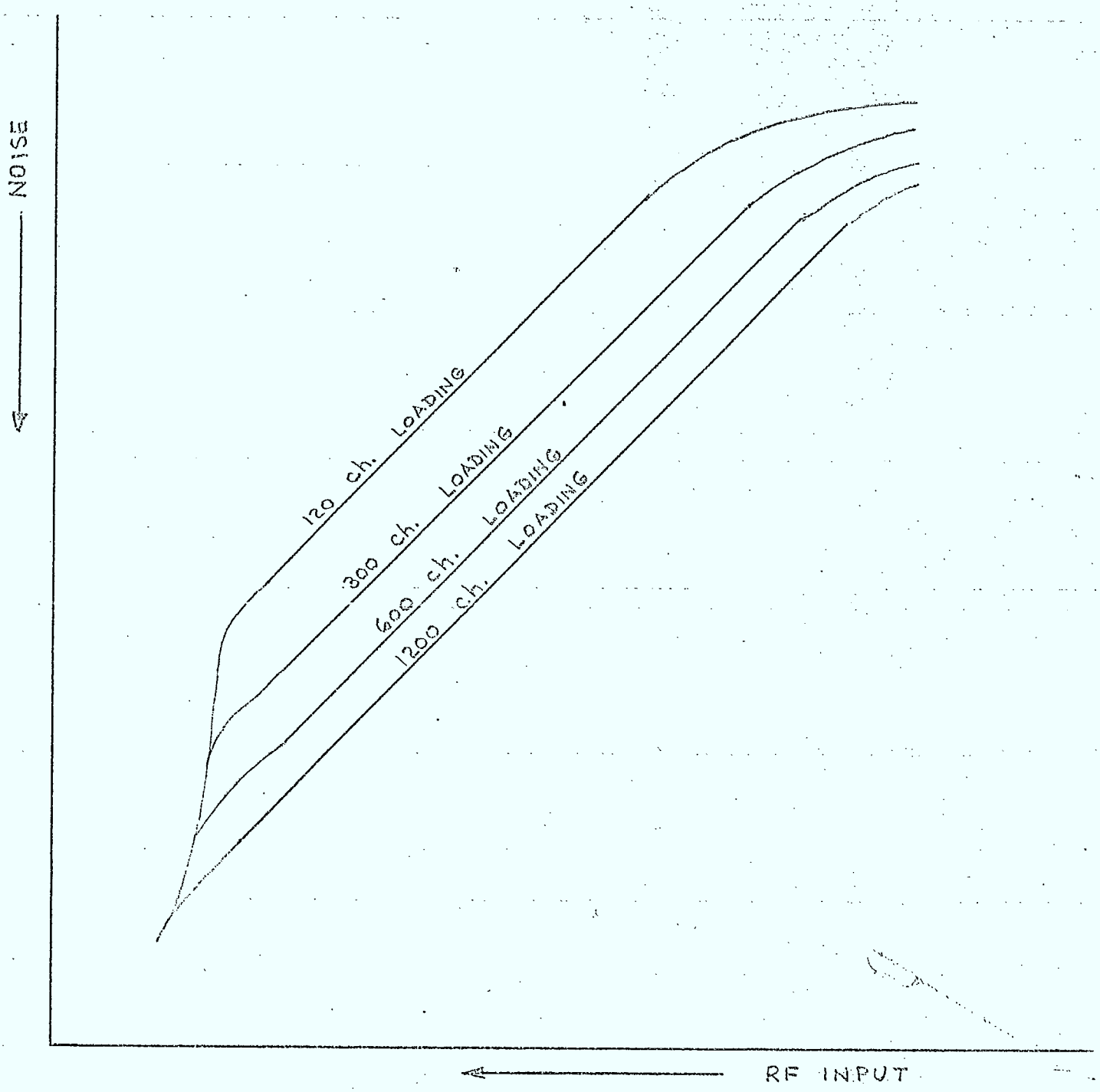
PHASE DISTORTION






DB UNWEIGHTED
INTERMODULATION NOISE 600 CW LOADING
INTERMODULATION NOISE 1800 CW LOADING
600 CW LOADING
PRACTICAL THRESHOLD
MEDIAN INPUT LEVEL
-60
-50
-40
-30
-20
RECEIVED INPUT NOISE

TOP CHANNEL NOISE



PAGES 137 AND 138 GIVES DEFINITIONS OF 19 NOISE MEASURING UNITS. WE WILL DISCUSS IN DETAIL SOME OF THEM.

WE HAVE ALREADY DISCUSSED THE UNITS db, dbm AND dbw IN THE PREVIOUS PORTION OF THE COURSE. ALL THESE UNITS EXPRESS RELATIVE OR ABSOLUTE POWER UNITS. WE WILL NOW DISCUSS THE UNITS USED FOR MEASURING NOISE IN A VOICE FREQUENCY CHANNEL.

THE UNITS dba AND dbrn ARE CLOSELY RELATED UNITS: IN FACT dba MEANS dbrn ADJUSTED. BOTH TERMS ORIGINATED FROM RESEARCH DONE AT BELL LABRATORIES. SINE NOISE MAY CONSIST OF RANDOM FREQUENCIES WITH WIDELY VARYING AMPLITUDES, IT WAS NECESSARY TO EVALUATE THE INTERFERING EFFECTS OF SINGLE FREQUENCIES TO OBTAIN USABLE DATA.

A LARGE NUMBER OF LISTENING TESTS WERE MADE WITH DIFFERENT TONES INTRODUCED AS INTERFERENCE. THE DEGREE OF INTERFERENCE WAS DETERMINED BY COMPARING THE POWER OF EACH TONE WITH THE POWER OF 1000 HZ TONE THAT

DEFINITION OF NOISE MEASURING UNITS.

1. dBa — (dBrn adjusted) Weighted circuit noise power in dB referred to 3.16pW (-85dBm) which is 0dBa.
Use of weighting indicated in parenthesis as required.

2. dBa — (F1A) Weighted circuit noise in dBa measured on a line by a noise measuring set with F1A weighting.
Note: 1mW of a 1kc mod. tone reads +85dBa, but the same white noise power (300-3400cps) will read +82dBa due to frequency weighting.

3. dBa — (HA1) Weighted circuit noise power in dBa measured across a 302 type receiver with HA1 receiver weighting.

4. dBa0 — Circuit noise power in dBa referred to or measured at a point of zero relative transmission level (0dBr or 0TLP).
Note: It is preferred to convert circuit noise readings from dBa to dBa0 as this makes it unnecessary to know or state the relative transmission level at point of actual measurement.

5. dBm — Power in dB relative to 1mW.

6. dBm0 — dBm referred to or measured at a point of zero transmission level.

7. dBmp — (dBm psophometrically weighted) Unit of noise power in dBm measured with psophometric weighting. Conversion as follows:

$dBm(psoph) = 10 \log_{10} pWp - 90 = dBa - 84 = dBm - 2.5$ (for flat noise 300-3400cps).

8. dBm0p — Circuit noise in dBm0 measured on a line with a noise measuring set having psophometric weighting.

9. dBr — dB relative to point of zero transmission level.

10. dBrn — (Decibels above reference noise) Weighted circuit noise power in dB ref. 1pW (-90dBm) which is 0dBrn. Type of weighting indicated in parenthesis.
Note: a) With 'C' message weighting, a 1mW 1kc tone will read +90dBrn, but the same power with white noise randomly distributed over a 3kc band (300-3400cps) will read +88dBrn.
b) With 144 weighting a 1mW 1kc tone will read +90dBrn, but a 3kc band of white noise will read +82dBrn due to the different frequency weighting.

11. dBrn — (144-line) Weighted circuit noise power in dBrn, measured on a line by a noise measuring set with 144 line weighting.

12. dBrn (144-receiver) Weighted circuit noise power in dBrn measured across the receiver of a subset with a 144-receiver by a noise measuring set with 144-receiver weighting.

13. dBrn or dBrnc (C-message) Weighted circuit noise power in dBrn, measured on a line by a noise measuring set with C message weighting.

14. dBrncO Noise measured in dBrnc referred to zero transmission level point. (OTLP)

15. dBrn (f_1 - f_2) Flat noise power in dBrn, measured over a frequency band between frequencies f_1 and f_2 (eg. 3kc flat).

16. OTLP Zero test level point (=0dBr), point of zero relative transmission level.

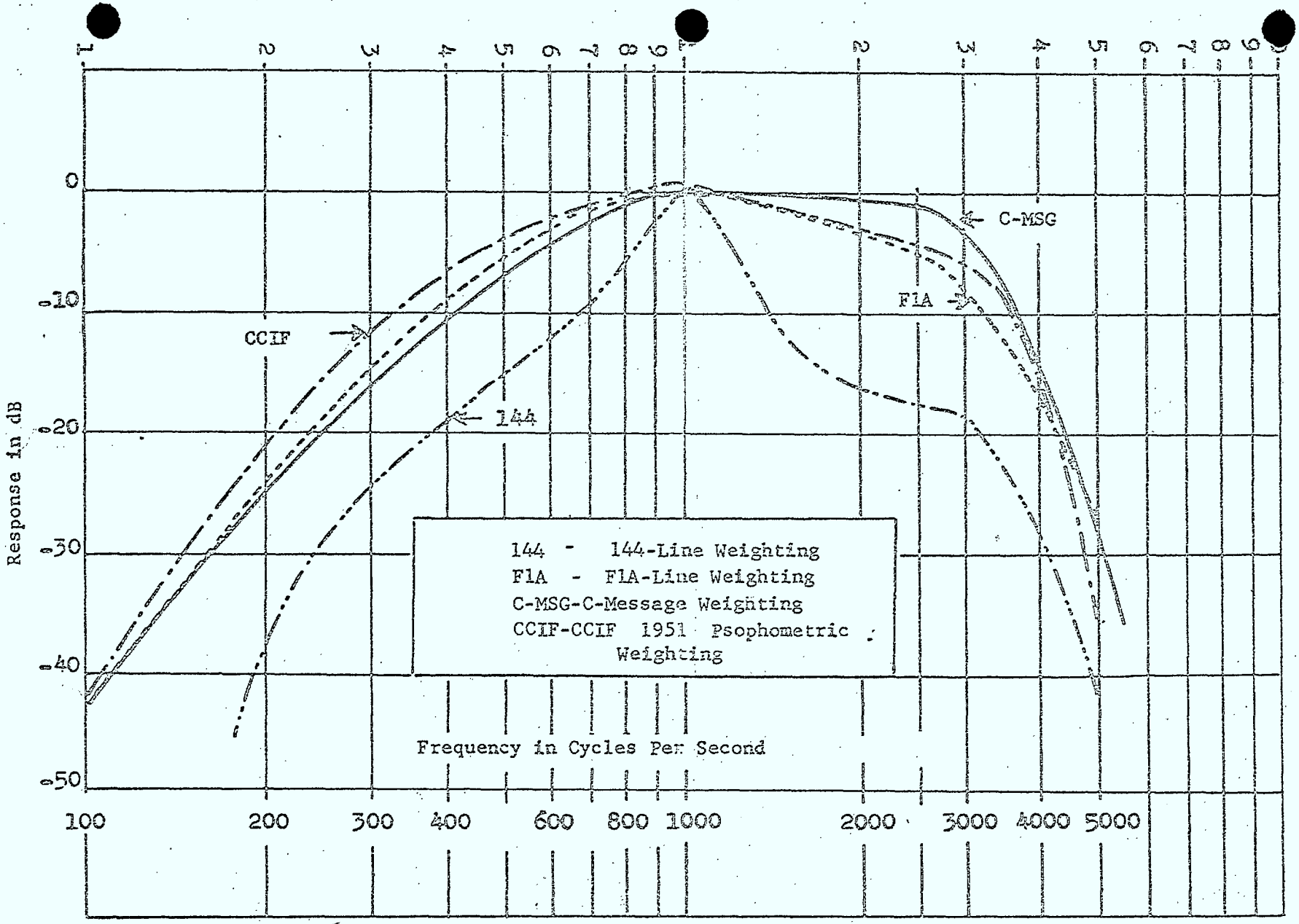
17. Psophometric Voltage or "Psophometric p.d." Circuit noise voltage measured on a line with psophometric weighting (CCIF 1951) applied.
Note: a) Do not confuse with psophometric emf, which is the emf of a generator or line with 600 ohm impedance. This is numerically double the psophometric voltage.
b) Psophometric voltage to dBmp conversion.
dBm(psoph) = 20 $\log_{10}$ V - 57.78
(V in psophometric millivolts)

18. pW (Picowatt equal to 10^{-12} watt or -90dBm) A unit of absolute power used for both weighted and unweighted noise.
10 $\log_{10}$ pW = dBm -90

19. pWp (pW psophometrically weighted) Noise power measured in picowatts via a CCIF psophometric filter.
pWp = 0.56pW (for flat noise 300-3400cps)

NOTE: See Fig. 2. for direct conversion of noise measuring units.

CREATED THE SAME DEGREE OF INTERFERENCE. FOR EXAMPLE, IF THE INTERFERING EFFECT OF A PARTICULAR TONE WAS TO BE DETERMINED, THAT TONE WAS SUPERIMPOSED ON A SPECIALLY SELECTED CONVERSATION AT A REFERENCE POWER LEVEL. WHEN THE INTERFERING TONE WAS REMOVED, A 1000 HZ TONE WAS SUPERIMPOSED ON THE SAME CONVERSATION AND ITS POWER LEVEL ADJUSTED UNTIL THE LISTENER JUDGED THAT IT HAD THE SAME INTERFERING EFFECT. THE DIFFERENCE NOTED BETWEEN THE POWER LEVELS OF THE SELECTED TONE AND THE 1000 HZ CYCLE TONE WAS THEN CONSIDERED TO BE THE DIFFERENCE IN INTERFERING EFFECT. WHEN THIS SAME TEST WAS PERFORMED FOR A NUMBER OF DIFFERENT TONES IN THE VOICE FREQUENCY CHANNEL AND FOR A NUMBER OF DIFFERENT LISTENERS USING THE SAME TELEPHONE SET, IT WAS POSSIBLE TO PLOT A GRAPH FOR EACH TYPE OF TELEPHONE SETS SUCH AS THOSE SHOWN ON PAGE 140.



LINE WEIGHTINGS FOR TELEPHONE MESSAGE CIRCUIT NOISE

THE GRAPH ON PAGE 140, CALLED WEIGHTING CURVES, SHOWS THE RELATIVE INTERFERING EFFECTS OF DIFFERENT FREQUENCIES IN THE V.F. CHANNEL SPECTRUM COMPARED TO 1000 HZ.

IT WAS FOUND THAT AN INTERFERING 1000 HZ TONE AT -90 dbm HAS AN EXTREMELY NEGLIGIBLE INTERFERING EFFECT. HENCE THE TONE AT 1000 HZ AND -90 dbm POWER WAS USED AS THE REFERENCE POWER, AND ALL OTHER NOISE POWERS LIKELY TO BE ENCOUNTERED WOULD HAVE A POSITIVE INTERFERING EFFECT THAT COULD BE EXPRESSED IN db ABOVE REFERENCE NOISE OF -90 dbm AT 1000 HZ OR IN ABBREVIATED FORM AS dbrn.

THE EARLY EXPERIMENTS WERE CARRIED WITH THE WESTERN ELECTRIC 144 HANDSET. LATER AN IMPROVED HANDSET, THE WESTERN ELECTRIC F1A, CAME INTO GENERAL USE. SIMILAR TESTS WITH THE NEW HANDSET INDICATED THAT THE F1A GAVE APPROXIMATELY A 5 db IMPROVEMENT OVER THE ELECTRICAL AND ACCOUSTICAL PERFORMANCE OF THE 144. BECAUSE OF THE DIFFERENCES IN SENSITIVITY AND FREQUENCY RESPONSE, NOISE

NOISE MEASUREMENTS WITH THE FIA WEIGHTING PROVIDED INDICATIONS ABOUT 5 db HIGHER THAN WITH THE 144 WEIGHTING. RATHER THAN CHANGE EXISTING STANDARDS, A NEW REFERENCE NOISE POWER OF -85 dbm WAS INTRODUCED WHICH PRODUCED IDENTICAL NOISE MEASURING SET READINGS OF EQUAL TRANSMISSION IMPAIRMENTS. THE CHANGE IN REFERENCE NOISE POWER NECESSITATED A CHANGE IN THE UNITS USED TO EXPRESS INTERFERING EFFECT AND RESULTED IN THE ADOPTION OF A NEW UNIT CALLED dba WHICH MEANS DECIBEL ADJUSTED.

WITH THE INTRODUCTION OF 500 TYPE HANDSET, THE C MESSAGE WEIGHTING WAS INTRODUCED, AND THE REFERENCE NOISE POWER WAS REVERTED AGAIN TO -90 dbm. THE UNIT RELATED TO THE C MESSAGE WEIGHTING IS THE dbrnc.

TELEPHONE NOISE MEASURING SETS HAD TO TAKE INTO ACCOUNT THESE DIFFERENT CHARACTERISTICS OF THE TELEPHONE HANDSETS. ACCORDINGLY RMS NOISE MEASURING

SETS WERE DESIGNED, WHICH HAVE THESE CURVES INCORPORATED INTO THEM. THIS MEANT THAT ANYWHERE ALONG THE CIRCUIT THE EFFECTIVE NOISE THAT WOULD BE RECEIVED BY THE LISTENER USING A TELEPHONE SET COULD BE MEASURED.

OUTSIDE NORTH AMERICA, THE INTERNATIONAL STANDARD TELEPHONE WEIGHTING CHARACTERISTICS IS CALLED THE CCIF PSOPHOMETER CURVE. IN THIS CASE THE REFERENCE FREQUENCY USED WAS 800 HZ AND THE NOISE UNIT WAS EITHER EXPRESSED IN MILLIWATTS (dbmp) OR PICOWATTS (pwp). A PICOWATT IS TEN WATTS TO THE POWER OF -12.

THE FOLLOWING IS A COMPARISON TABLE OF VARIOUS NOISE MEASUREMENTS.

INTERFERING NOISE AT 0 dbm LEVEL

NOISE UNIT	1000 HZ	0 TO 3 KHZ	WHITE NOISE OF -4.8 dbm/KHZ
dbrnc	90 dbrnc	88 dbrnc	88.4 dbrnc
dbrn 3KC FLAT	90 dbrn	88.8 dbrn	90.3 dbrn
dbrn 15KC FLAT	90 dbrn	90 dbrn	97.3 dbrn
dba	85 dba	82 dba	82 dba
PSOPHOMETRIC VOLTAGE (600 ohms)	870 MV	582 MV	604 MV
PSOPHOMETRIC EMF	1740 MV	1164 MV	1208 MV
PWP	1.26×10^9 PWP	5.62×10^8 PWP	6.03×10^8 PWP
DBP	91 DBP	87.5 DBP	87.8 DBP

IN A LONG SYSTEM WHERE A STRING OF LOSSES AND GAINS PRODUCED BY CABLE SECTIONS, REPEATERS, AND OTHER COMPONENTS IS ENCOUNTERED, IT IS NECESSARY TO ACCOUNT FOR THE SIGNAL MAGNITUDE AT MANY POINTS RELATIVE OT ITS MAGNITUDE AT OTHER POINTS. THIS IS ACCOMPLISHED BY CHOOSING A REFERENCE POINT, CALLED THE TRANSMISSION LEVEL POINT. IN THE INTEREST OF CONVENIENCE AND UNIFORMITY, THE REFERENCE POINT IS DEFINED AS THE 0 db TRANSMISSION LEVEL POINT (OTLP).

EXAMPLE: - NOISE MEASURED AT 1000 HZ IS 32 dBrnc0 AND ON A BANDWIDTH OF 0 TO 3 KH_Z. FIND IN THE FOLLOWING UNITS: - dbrno 3KC FLAT, dbrno 15 KC FLAT, dbao, dbpo -

90 - 32 = 58 db

dbrnco	0 - 3 KH_Z,	88 - 58 =	30 dbrnco -	
dbrno 3KC FLAT	0 - 3 KH_Z,	88.8 - 58 =	30.8 dbrno - 1 KH_Z,	90 - 58 = 32 dbrno
dbrno 15 KC FLAT	0 - 3 KH_Z,	90 - 58 =	32 dbrno - 1 KH_Z,	90 - 58 = 32 dbrno
dbao	0 - 3 KH_Z,	82 - 58 =	24 dbao - 1 KH_Z,	85 - 58 = 27 dbao
dbpo	0 - 3 KH_Z,	87.5 - 58 =	29.5 dbpo - 1 KH_Z,	91 - 58 = 33 dbpo

THE TABLES SHOWN BELOW INDICATE HOW db MEASUREMENTS SHOULD BE ADDED

DIFFERENCE	TOTAL*	DIFFERENCE	TOTAL*
0	3 db	3.6	1.57
.1	2.96 db	3.8	1.51
.2	2.92	4.0	1.46
.3	2.86	4.2	1.4
.4	2.81	4.4	1.34
.5	2.77	4.6	1.29
.6	2.72	4.8	1.24
.7	2.67	5.0	1.19
.8	2.63	5.5	1.08
.9	2.58	6.0	.98
1.0	2.54	6.5	.84
1.1	2.49	7.0	.78
1.2	2.45	7.5	.71
1.3	2.4	8.00	.64
1.4	2.37	8.5	.58
1.5	2.32	9.0	.52
1.6	2.28	9.5	.47
1.7	2.24	10	.42
1.8	2.2	11	.33
1.9	2.16	12	.27
2.0	2.12	13	.22
2.2	2.05	14	.16
2.4	1.98	15	.14
2.6	1.9	16	.11
2.8	1.8	17	.09
3.0	1.78	18	.07
3.2	1.7	19	.06
3.4	1.63	20	.04

* BY ADDING TO THE HIGHER OF THE TWO POWERS

EXAMPLE: - FOUR SOURCES OF NOISE EXIST ON A CIRCUIT WITH THE FOLLOWING MAGNITUDES 10 dbrnco, 9 dbrnco, 8.8 dbrnco, AND 2 dbrnco. FIND THE TOTAL NOISE IN THE CIRCUIT.

10 dbrnco IS THE HIGHEST NOISE.

10 + 9 dbrnco = 12.54 dbrnco (SEE PAGE 146)

12.54 - 8.8 dbrnco = 3.74

12.54 + 8.8 dbrnco = 12.54 + 1.51 = 14.05 dbrnco

14.05 - 2 = 12.05

14.05 + 2 dbrnco = 14.05 + .27 = 14.32 dbrnco

TOTAL NOISE = 14.32 dbrnco

CCIR/CCIT HYPOTHETICAL REFERENCE CIRCUIT

IN ORDER TO PROVIDE A BASIS ON WHICH TO ESTABLISH NOISE OBJECTIVES CCIR/CCITT MAKE REFERENCE TO A "HYPOTHETICAL REFERENCE CIRCUIT" (h.r.c.). AT THE PRESENT TIME THE h.r.c. FOR LINE-OF-SITE SYSTEMS WITH CAPACITIES GREATER THAN 120 VOICE CIRCUITS PER RF CHANNEL IS 2500 km LONG AND IS COMPOSED OF NINE HOMOGENEOUS MODULATION SECTIONS.

IT SHOULD BE NOTED THAT WHILE CCIR/CCITT HAVE DEFINED THE MULTIPLEX ARRANGEMENT AT EACH OF THE RADIO DEMODULATION POINTS, THE NOISE OBJECTIVES ESTABLISHED FOR THIS CIRCUIT EXCLUDE THE CONTRIBUTION OF THIS EQUIPMENT.

THE CCIR HAVE PROPOSED THE FOLLOWING RECOMMENDED NOISE PERFORMANCE VALUES FOR THE HYPOTHETICAL REFERENCE CIRCUIT:

"THE NOISE POWER AT A POINT OF ZERO RELATIVE LEVEL FOR ANY TELEPHONE CHANNEL ON THE 2500 km h.r.c. SHOULD NOT EXCEED THE FOLLOWING VALUES".

(i) 7500 PW (PSOPHOMETRICALLY WEIGHTED), MEAN POWER IN ANY HOUR.

(ii) 7500 PW (PSOPHOMETRICALLY WEIGHTED), ONE MINUTE MEAN POWER FOR MORE THAN 20% OF ANY MONTH.

(iii) 47,500 PW (PSOPHOMETRICALLY WEIGHTED), ONE MINUTE MEAN POWER FOR MORE THAN 0.1% OF ANY MONTH.

(iv) 1,000,000 PW (UNWEIGHTED), (WITH AN INTERGRATING TIME OF 5ms) FOR NOT MORE THAN 0.01% OF ANY MONTH.

NOTE THAT THE SIGNIFICANCE OF "ANY HOUR" IN (i) IMPLIES THE "BUSY HOUR" DURING THE WORST PERIOD OF PROPAGATION.

THE EQUIVALENT "WHITE NOISE" LOADING LEVEL REPRESENTING THE TELEPHONE TRAFFIC IN THE "BUSY HOUR" HAS BEEN DEFINED BY CCIR AS: -15 + 10 LOG N dbmO (FOR N GREATER THAN 240) WHERE N IS THE NUMBER OF VOICE CHANNELS.

THE "ONE-MINUTE MEAN" USED IN (ii) AND (iii) CORRESPONDS TO THE AVERAGE DURATION OF TELEPHONE CALLS. THE "INTERGRATING TIME OF 5 ms" IN (IV) IS RELATED TO THE REQUIREMENTS OF TELEPHONE SIGNALLING AND TELEGRAPHY CHARACTERISTICS.

REAL CIRCUITS

IN ORDER TO APPLY THESE OBJECTIVES TO REAL SYSTEMS CCIR HAVE MADE A FURTHER RECOMMENDATION FOR SYSTEMS THAT DO NOT DIFFER APPRECIABLY FROM THE h.r.c. AND ARE BETWEEN 280 AND 2500 KM LONG:

"NOISE POWER (PSOPHOMETRICALLY WEIGHTED) AT A POINT OF ZERO RELATIVE LEVEL FOR ANY TELEPHONE CHANNEL OF A SYSTEM OF LENGTH L km SHOULD NOT EXCEED:

(i) 3L pw, MEAN POWER IN ANY HOUR.

(ii) 3L pw, ONE-MINUTE MEAN POWER FOR MORE THAN 20% OF ANY MONTH.

(iii) 47,500 pw ONE-MINUTE MEAN POWER FOR MORE THAN (L/2500) X 0.1% OF ANY MONTH.

NOTE: THIS THIRD RECOMMENDATION IS TO BE TAKEN AS A "PLANNING OBJECTIVE" AS IT IS RECOGNIZED THAT THIS IS EXTREMELY DIFFICULT TO MEASURE.

THE ABOVE ARE BASED ON THE FINDINGS THAT, FOR LOW NOISE LEVELS ((i) AND (ii)) OCCURING FOR THE GREATER PERCENTAGE OF THE TIME, NOISE POWER TENDS TO BE DIRECTLY PROPORTIONAL TO SYSTEM LENGTH: AND THAT FOR HIGH NOISE LEVELS (iii) OCCURING FOR RELATIVELY SHORT PERIODS OF TIME THE TOTAL TIME AT A GIVEN NOISE LEVEL TENDS TO BE DIRECTLY PROPORTIONAL TO SYSTEM LENGTH. THIS LATTER IS JUSTIFIED ON THE GROUNDS THAT DEEP FADES WHICH PRODUCE HIGH NOISE LEVELS ARE GENERALLY OF SUCH SHORT DURATION THAT THEY OCCUR FOR VERY SMALL PERCENTAGES OF THE TIME AND ARE UNLIKELY TO COINCIDE.

IT SHOULD BE NOTED THAT: -

dbp = 10 LOG (PWP)

pwp = ANTILOG (dbp/10)

BELL SYSTEM HYPOTHETICAL REFERENCE CIRCUIT

TRANSMISSION OBJECTIVES FOR BOTH LONG-HAUL AND SHORT-HAUL SYSTEMS ARE SUMMARIZED BELOW:

OBJECTIVE	LONG-HAUL SYSTEM	SHORT-HAUL SYSTEM
Noise		
4000 MILES	41 dbrnco	NOT APPLICABLE
250 MILES	29 dbrnco	32 dbrnco
RELIABILITY		
TOTAL TWO-WAY ANNUAL OUTAGE	0.02% (4000 MILES)	0.02 % (250 MILES)

THE BELL SYSTEM HYPOTHETICAL REFERENCE CIRCUIT INCLUDES THE MULTIPLEX NOISE. ON THE 4,000 MILES SYSTEM ALLOWANCES ARE MADE FOR 2 X 16 MULTIPLEXES.

REAL CIRCUITS

A REAL CIRCUIT COVERING DISTANCES SHORTER THAN 4,000 MILES SHOULD HAVE A PRORATED RELIABILITY BY USING THE FORMULA: -

THE NOISE OBJECTIVE FOR A SYSTEM D MILES LONG =
41 - 10 LOG (4000/D)

EXAMPLE: - A LONG-HAUL SYSTEM IS 975 MILES LONG. FIND THE NOISE OBJECTIVE IT SHOULD MEET.

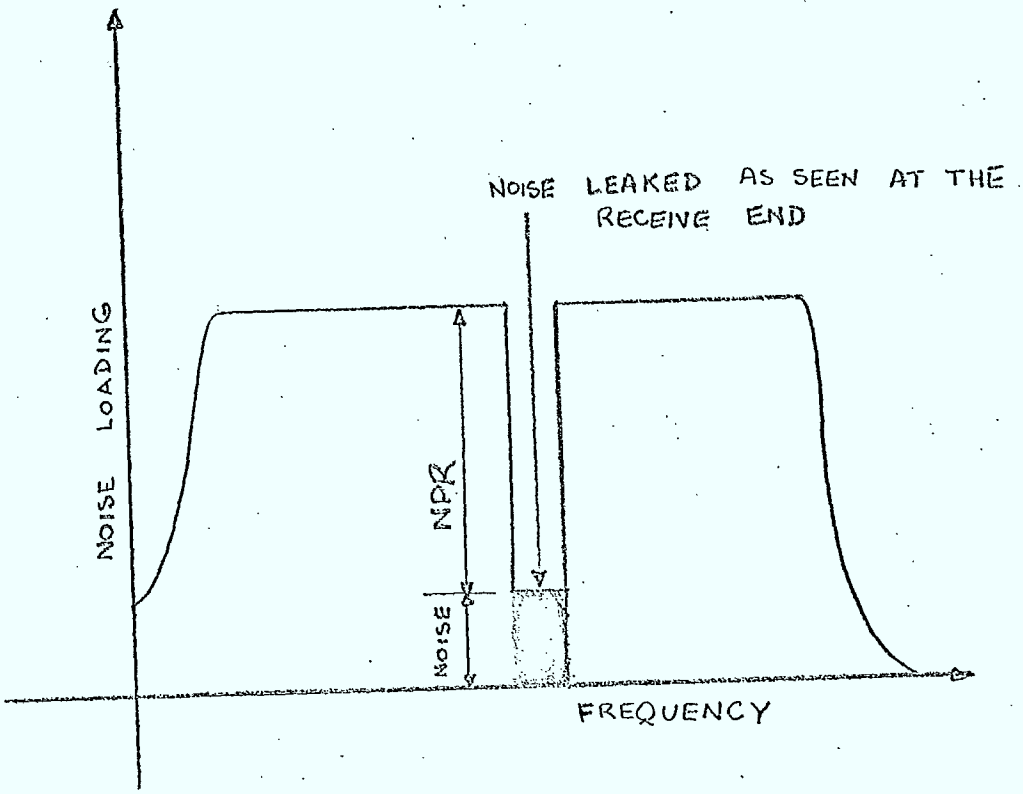
OBJECTIVE = 41 - 10 LOG (4000/975)

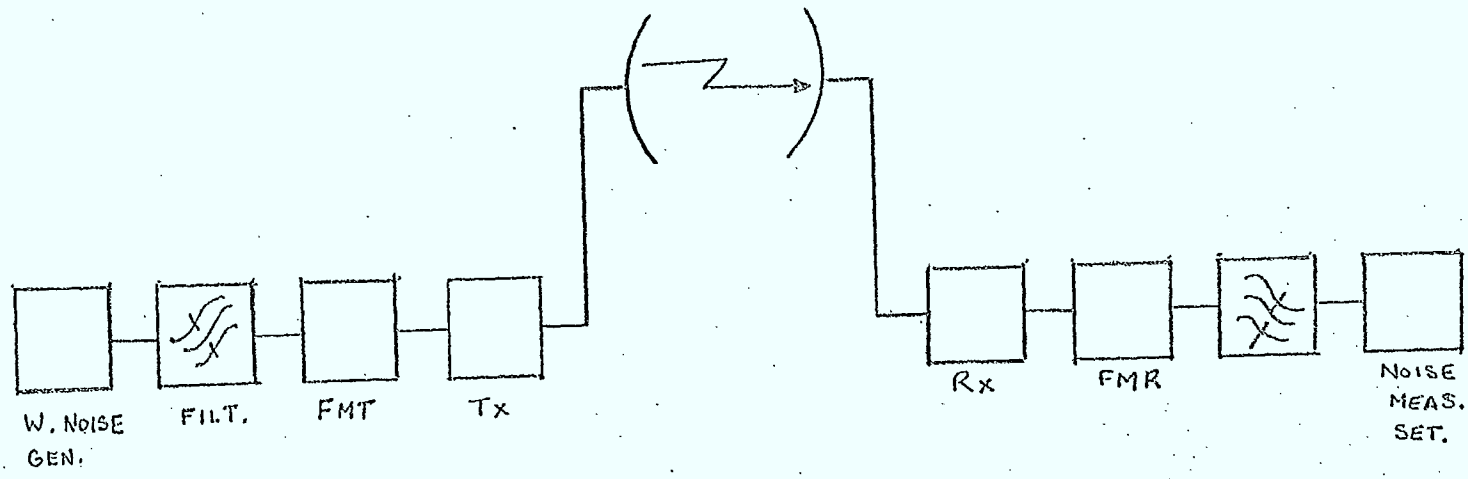
= 41 - 10 LOG 4.1 = 41 - 6.13

= 34.87 dbrnco.

WHITE NOISE MEASUREMENTS

THE MOST COMMON NOISE TEST MADE ON A MICROWAVE SYSTEM IS THE WHITE NOISE TEST. THIS TEST IS PERFORMED BY CONNECTING A WHITE NOISE GENERATOR AT THE FIRST TRANSMITTING HOP OF THE SYSTEM. THE WHITE NOISE WILL COVER ALL THE BASEBAND OF A CERTAIN R.F. CHANNEL EXCEPT FOR A SINGLE VOICE CHANNEL IN THE BASEBAND WHERE A FILTER IS INSERTED AT THE TRANSMIT END. THIS FILTER IS TO CLEAR THE WHITE NOISE IN A PARTICULAR VOICE SLOT. AT THE RECEIVE END OF THE SYSTEM A WHITE NOISE MEASURING SET IS TUNED TO MEASURE THE AMOUNT OF NOISE THAT HAS LEAKED IN THE CLEANED SLOT. THE GRAPHS ON PAGE 135 ARE DERIVED FROM SUCH A TEST. THE VARIOUS CHANNEL LOADING IS DERIVED BY INSERTING DIFFERENT FILTERS TO CLEAR A SLOT EQUIVALENT TO THE 120TH, 300TH, 600TH, OR 1200TH BASEBAND CHANNELS. (SEE PAGE 151)


NOISE LEAKED AS SEEN AT THE RECEIVE END
NOISE LOADING
NPR
NOISE
FREQUENCY


W. NOISE GEN.
FILT.
FMT
Tx
Rx
FMR
NOISE MEAS. SET.

BELL SYSTEM STEADY STATE NOISE OBJECTIVE

AS SHOWN ON PAGE 153 THE APPROACH USED IN DERIVING CUSTOMER-TO-CUSTOMER NOISE OBJECTIVE: -

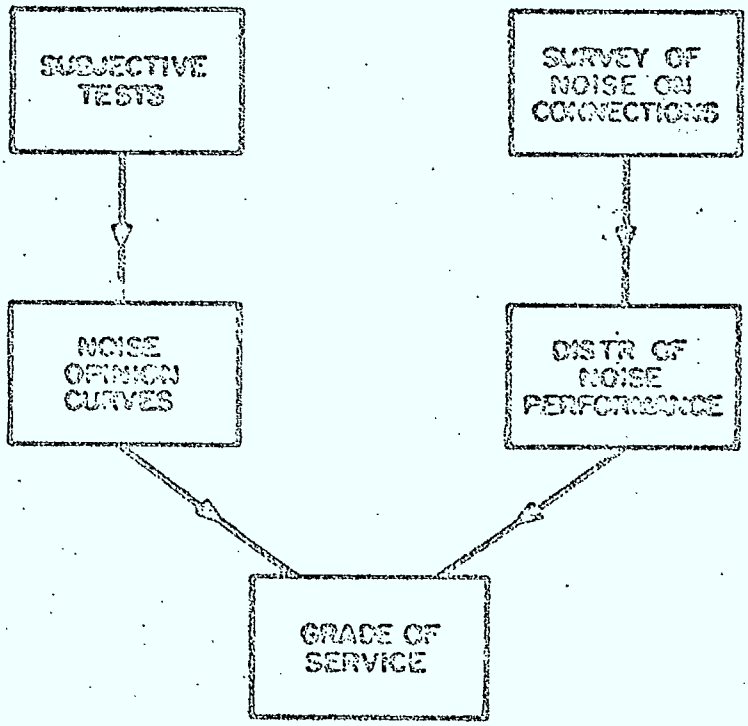
a) DETERMINE CUSTOMER TOLERANCE OF NOISE BY USE OF SUBJECTIVE TESTS.

b) DETERMINE NOISE PERFORMANCE OF TOLL NETWORK THROUGH MEASUREMENT SURVEYS.

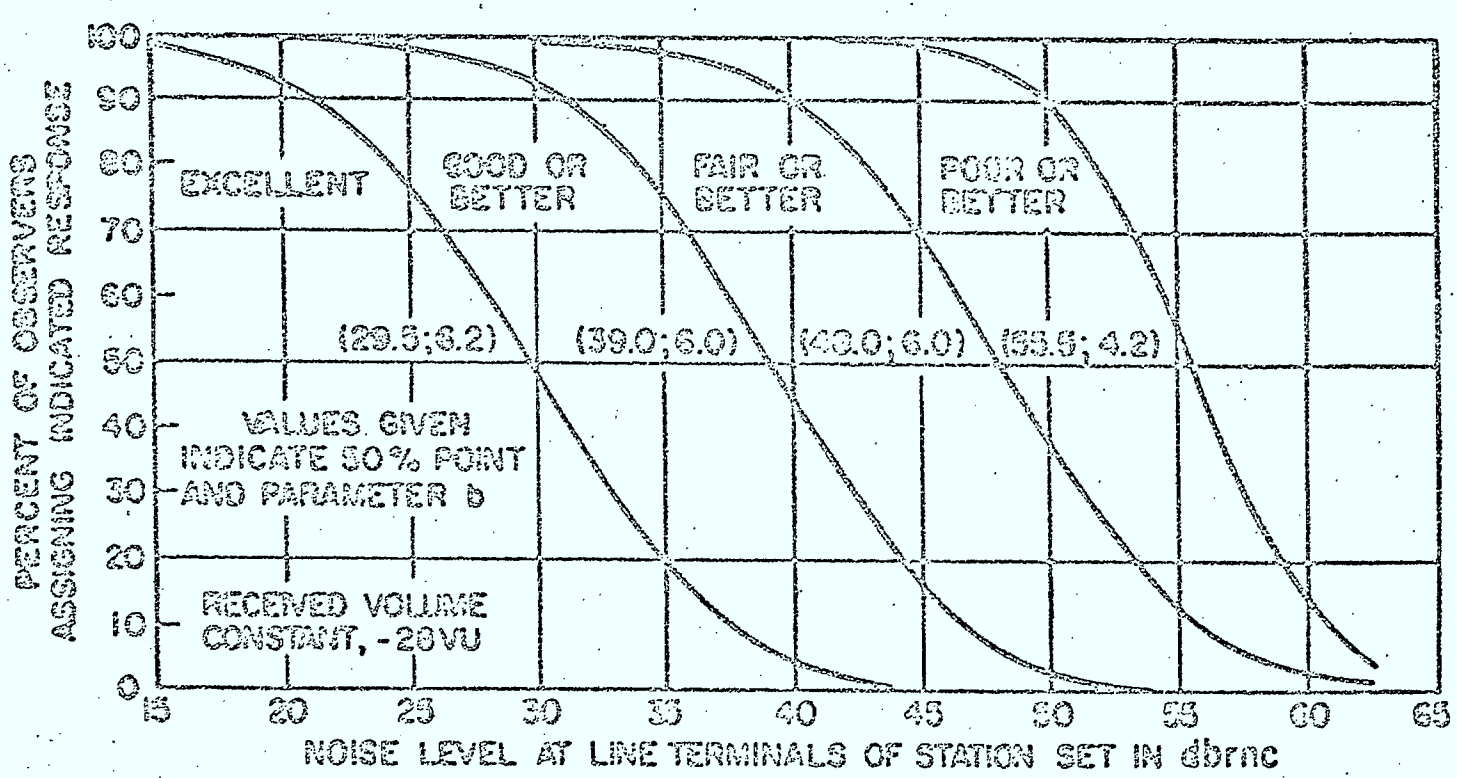
c) BY COMPARING BOTH A AND B THE GRADE OF SERVICE BEING RENDERED IS DETERMINED. ACCORDINGLY IF GRADE OF SERVICE IS NOT ADEQUATE, IMPROVEMENTS HAVE TO BE INCORPORATED IN THE NETWORK.

THE SUBJECTIVE "CUSTOMER TOLERANCE OF NOISE" TEST IS DONE BY USING A CERTAIN SET, RECENTLY THE 500, CONSTANT SPEECH LEVEL AND VARYING THE STEADY STATE NOISE LEVEL. THE SUBJECTS ARE ASKED TO RATE THE DIFFERENT CONNECTIONS AS EXCELLENT, GOOD, FAIR, POOR AND UNSATISFACTORY. THE RESULTS OF THE TESTS ARE SHOWN ON PAGE 154. FOR EXAMPLE 50% OF THE SUBJECTS THOUGHT THAT 30 dbrnc OF NOISE ON THE 500 SET GAVE AN EXCELLENT CONNECTION, WHILE 90% RATED 40 dbrnc FAIR OR BETTER.

THE NOISE SURVEY OF THE SWITCHED NETWORK WAS DIVIDED IN TWO PARTS; CUSTOMER LOOP SURVEY AND TOLL FACILITIES SURVEY FROM CLASS 5 OFFICE TO ANOTHER CLASS 5 OFFICE. (FOR MORE DETAILS SEE PAGES 155 AND 156).



- Approach Used in Deriving the Customer-to-Customer Noise Objectives

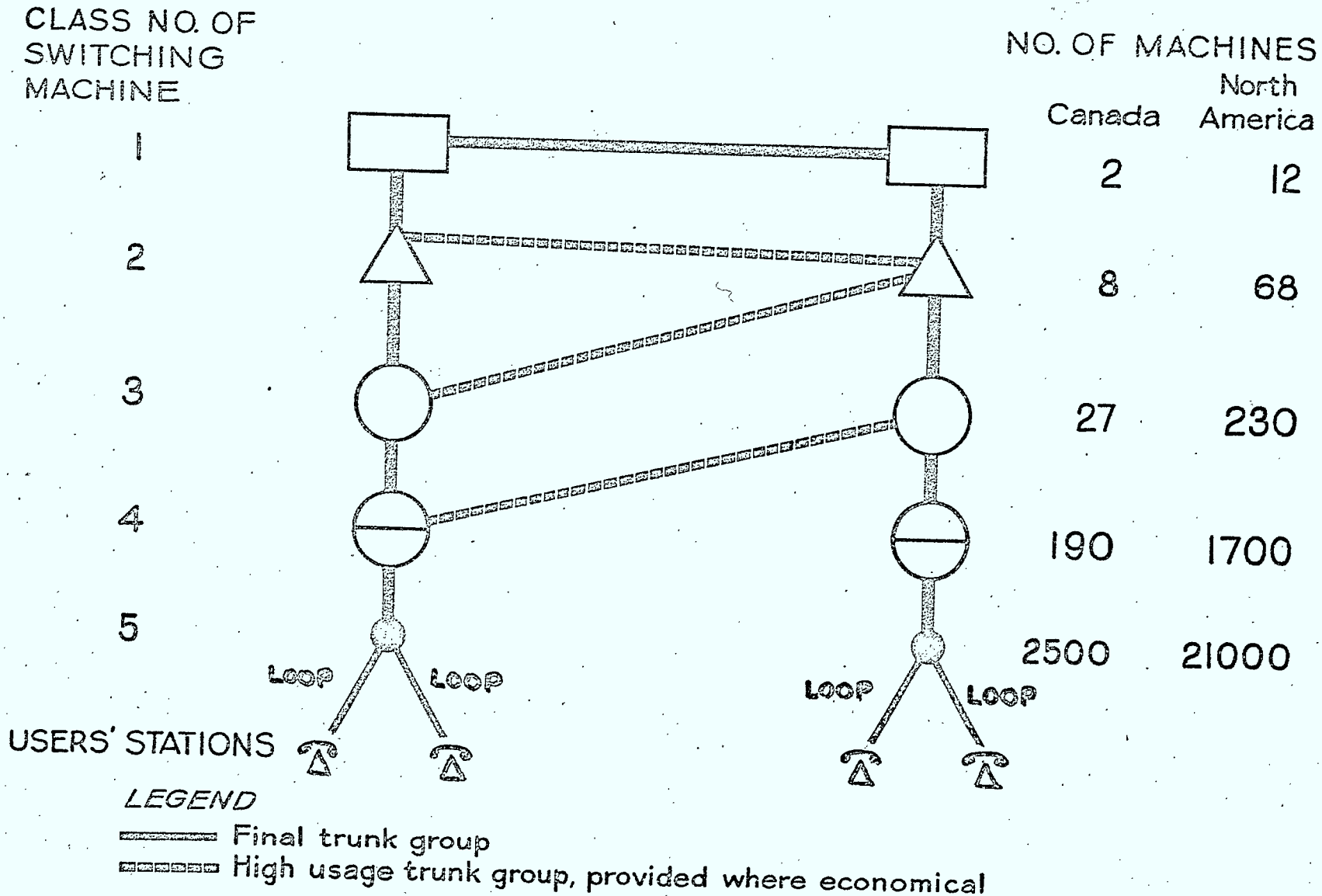


- Noise Opinion Curves

fig. 1

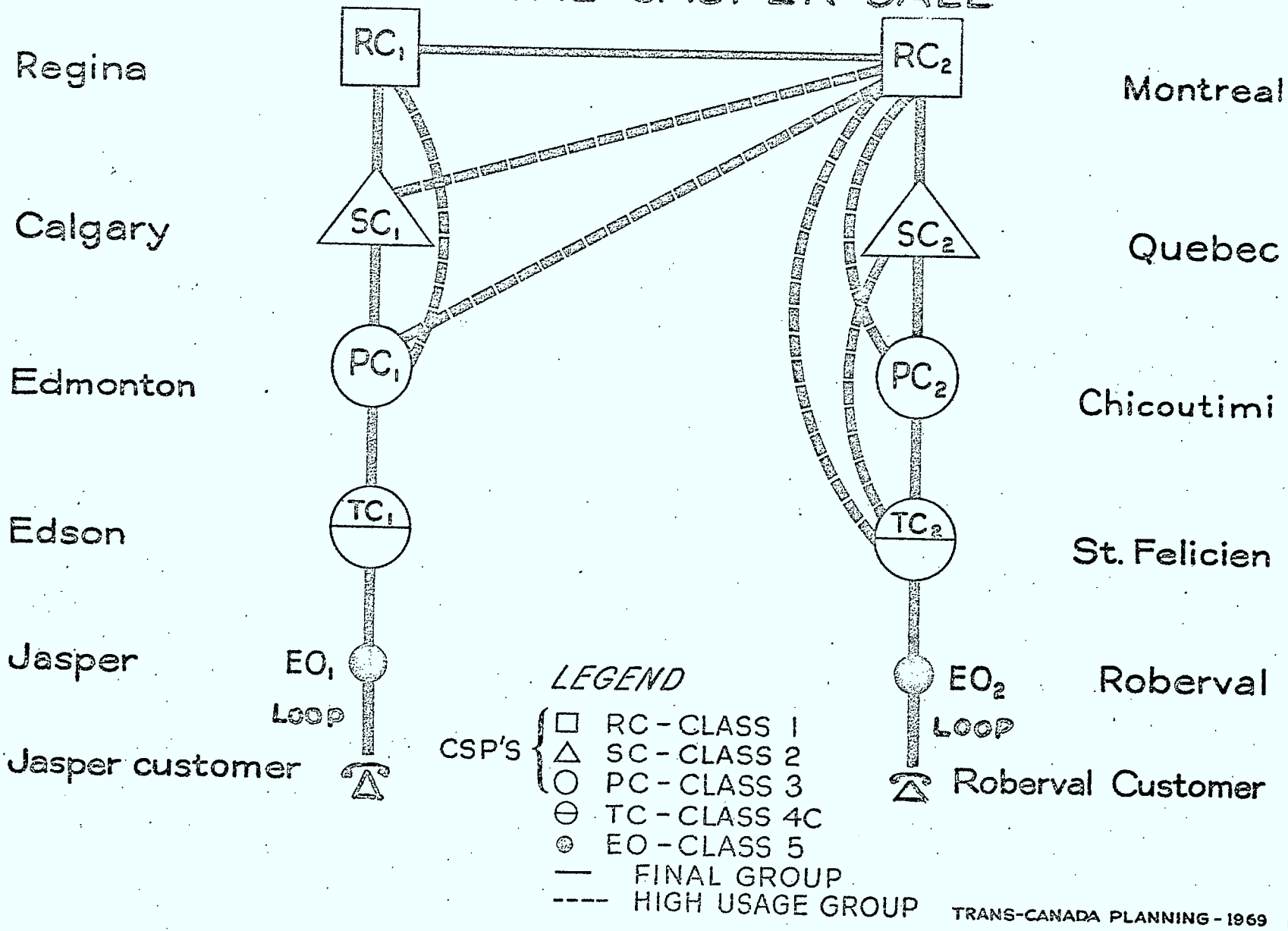
P. 154

NORTH AMERICAN SWITCHED NETWORK



TRANS-CANADA PLANNING-1969 L-5

SWITCHING PLAN (Routing Patterns)
SHOWING A ROBERVAL-JASPER CALL



TRANS-CANADA PLANNING - 1969 L-6

THE RESULTS OF THE 1964 LOOP SURVEY ARE SHOWN ON PAGE 158. THIS SURVEY SHOWED THAT 50% OF THE BELL SYSTEM LOOPS CONTRIBUTED LESS THAN 5 dbrnc OF NOISE ON THE CUSTOMER CONNECTION, WHILE 90% OF THE LOOPS CONTRIBUTED LESS THAN 20 dbrnc.

THE RESULTS OF THE BELL SYSTEM TOLL FACILITIES SURVEY SHOWED THAT FOR ALL DISTANCES 97% OF THE CONNECTIONS WERE GOOD OR BETTER WHILE 0.3% WERE POOR OR WORSE (SEE PAGE 159). THE GRAPH ON PAGE 159 SHOWS THAT FOR MEDIUM DISTANCES 50% OF THE CONNECTIONS WILL PRODUCE A NOISE OF 25 dbrnc FOR THE CUSTOMER. FROM THE SAME GRAPH YOU CAN SEE THAT THE PERFORMANCE OF LONG TOLL CONNECTIONS NEED IMPROVEMENT.

NOISE BUDGET ALLOCATION FOR TCTS

THE NOISE BUDGET IS DEFINED FOR A HYPOTHETICAL CIRCUIT 4000 MILES LONG ON A MICROWAVE SYSTEM WHICH HAS 16 SECTIONS OF 250 MILES EACH.

ITEM	QUANTITY	NOISE PER UNIT	TOTAL NOISE
T/R BAYS	140 HOPS	16.94 dbrnc	38.40 dbrnc
R.F. INTERFERENCE	140 HOPS	8.95 dbrnc	30.41 dbrnc
I.F. SWITCHING	27 SECTIONS	15.94 dbrnc	30.25 dbrnc
FM MODERN	32 TERMINALS	11.96 dbrnc	27.02 dbrnc
WLEL	32 RUNS	9.25 dbrnc	24.3 dbrnc
MUX	32 TERMINALS	19.53 dbrnc	35.3 dbrnc
TOTAL NOISE OF A 4000 MILES CIRCUIT			41 dbrnc

NOISE METALLIC AT MAIN STATION
(C-MESSAGE WEIGHTING)
(DIALED-UP TERMINATION)

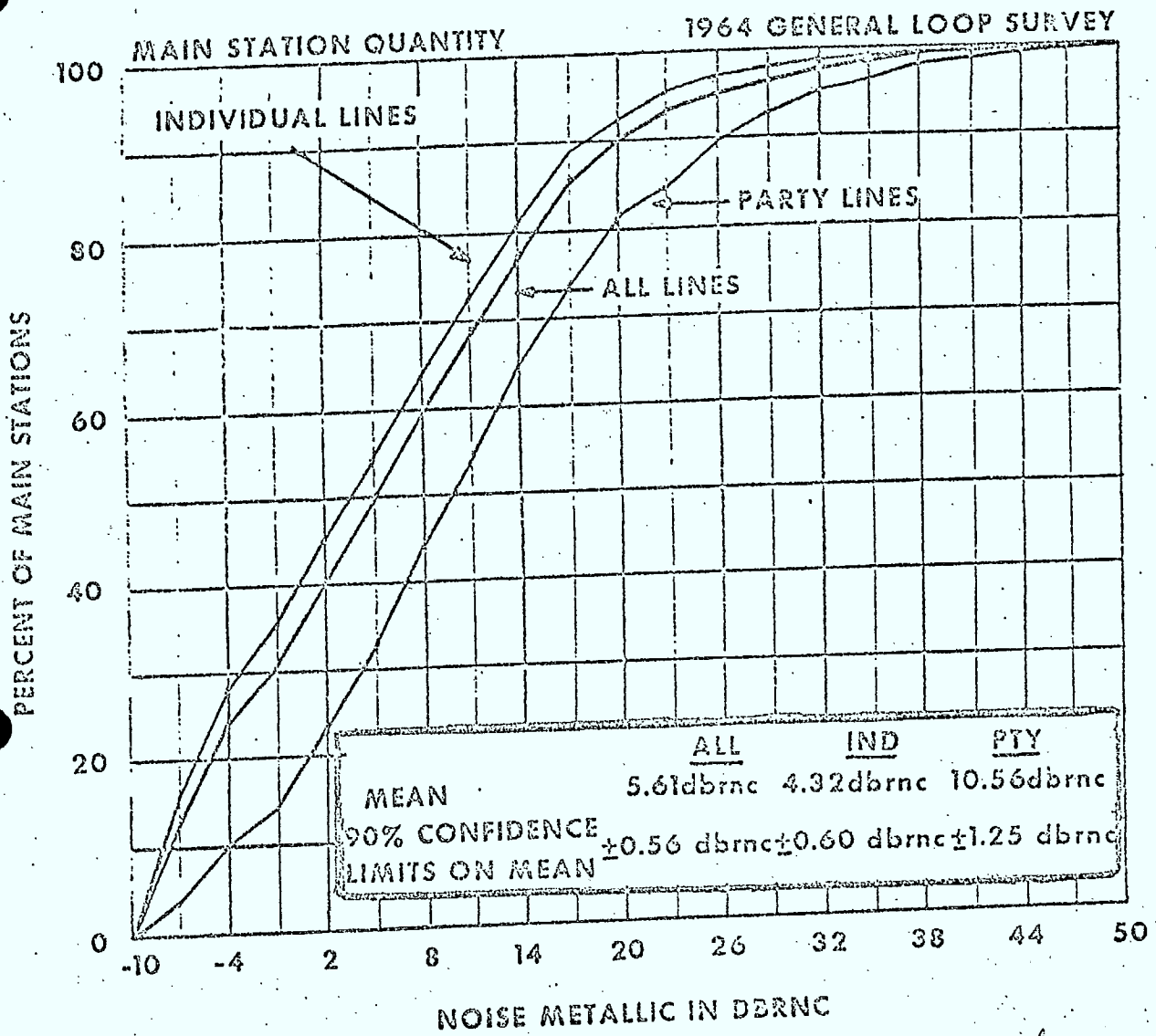


fig 2

This is the performance of our loops
This is dedicated & is always used

ATTACHMENT 35B

cl s to cl s measurement + avg noise in a-loop

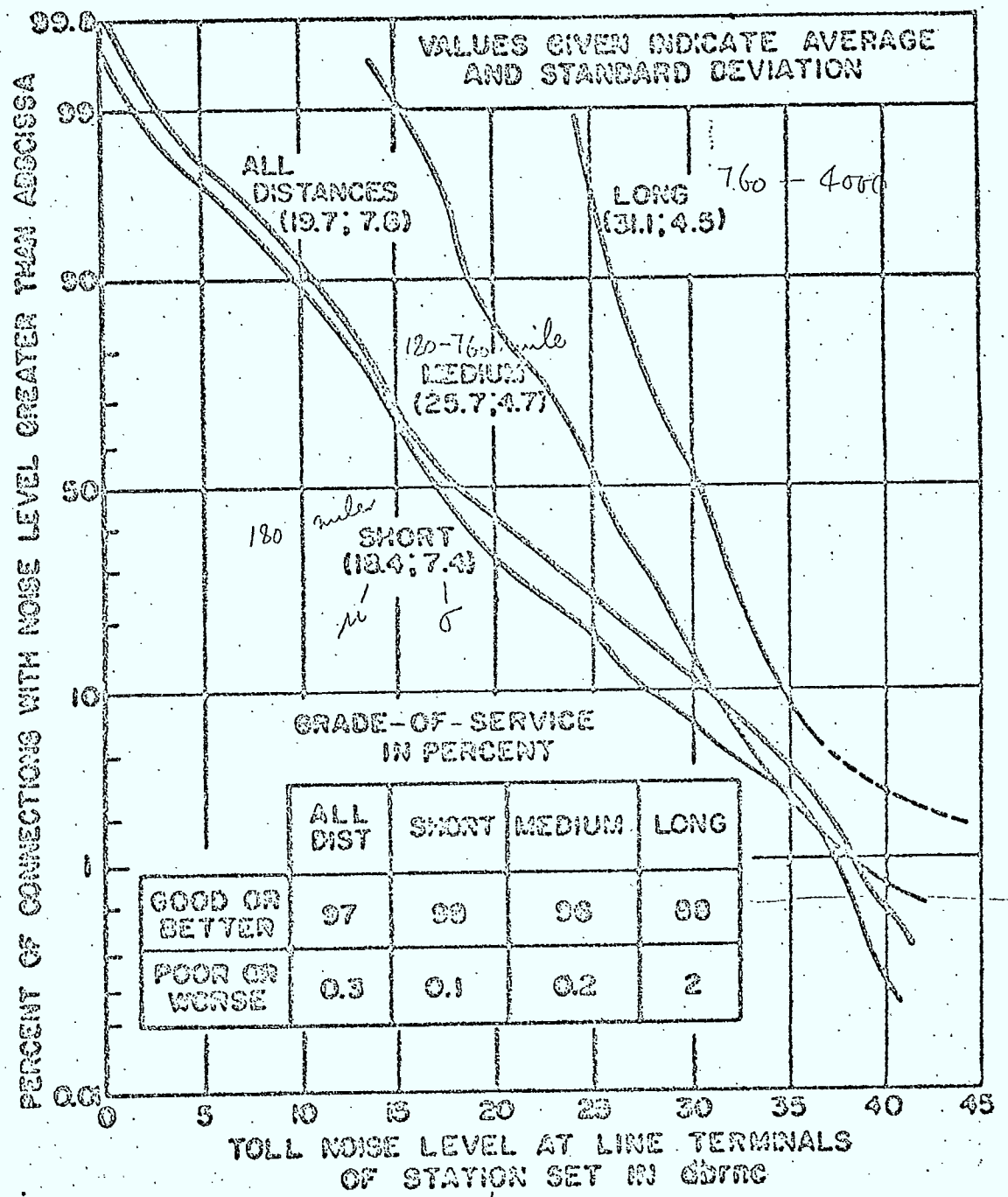


fig. 3

Trunk plant

- Estimated Toll Noise Distribution from 1962 Connection Survey Data

This is not always used

BECAUSE OF FADING CONDITIONS, FAILURE OF EQUIPMENT, MAINTENANCE CONSIDERATIONS, ETC. . . IT IS IMPOSSIBLE TO MAINTAIN A 4000 MILES SYSTEM OPERATING WITH A TOTAL NOISE OF 41 dbrnco ALL THE TIME. PAGE 161 INDICATES THE NOISE OBJECTIVES THAT SHOULD BE MAINTAINED FOR 50%, 98% AND 100% OF THE TIME.

THE NOISE PERFORMANCE OF VARIOUS SYSTEMS COMPARED TO THE OBJECTIVES IS GIVEN ON PAGES 162, 163 AND 164. THIS PERFORMANCE IS IN TERMS OF WORST CHANNEL ON THAT PARTICULAR CARRIER SYSTEM.

EXAMPLE: - SEE PAGES 165 AND 166 FOR DETAILS.

THE ONLY ACCEPTABLE PLAN ACCORDING TO THIS EXAMPLE IS PLAN C.

EXAMPLE: - THE FOLLOWING IS THE DESCRIPTION OF A $7GH_Z$ SYSTEM OPERATING ON A PATH 25 MILES LONG.

STATION A	STATION B
ANTENNA HEIGHT 100 FT	ANTENNA HEIGHT 200 FT
10' DISH ANTENNA	10' DISH ANTENNA
GAIN = 44.5 db	GAIN = 44.5 db

FREE SPACE LOSS = 36.6 + 20 LOG d + 20 LOG f

d = 25 MILES f = 7000 MH_Z

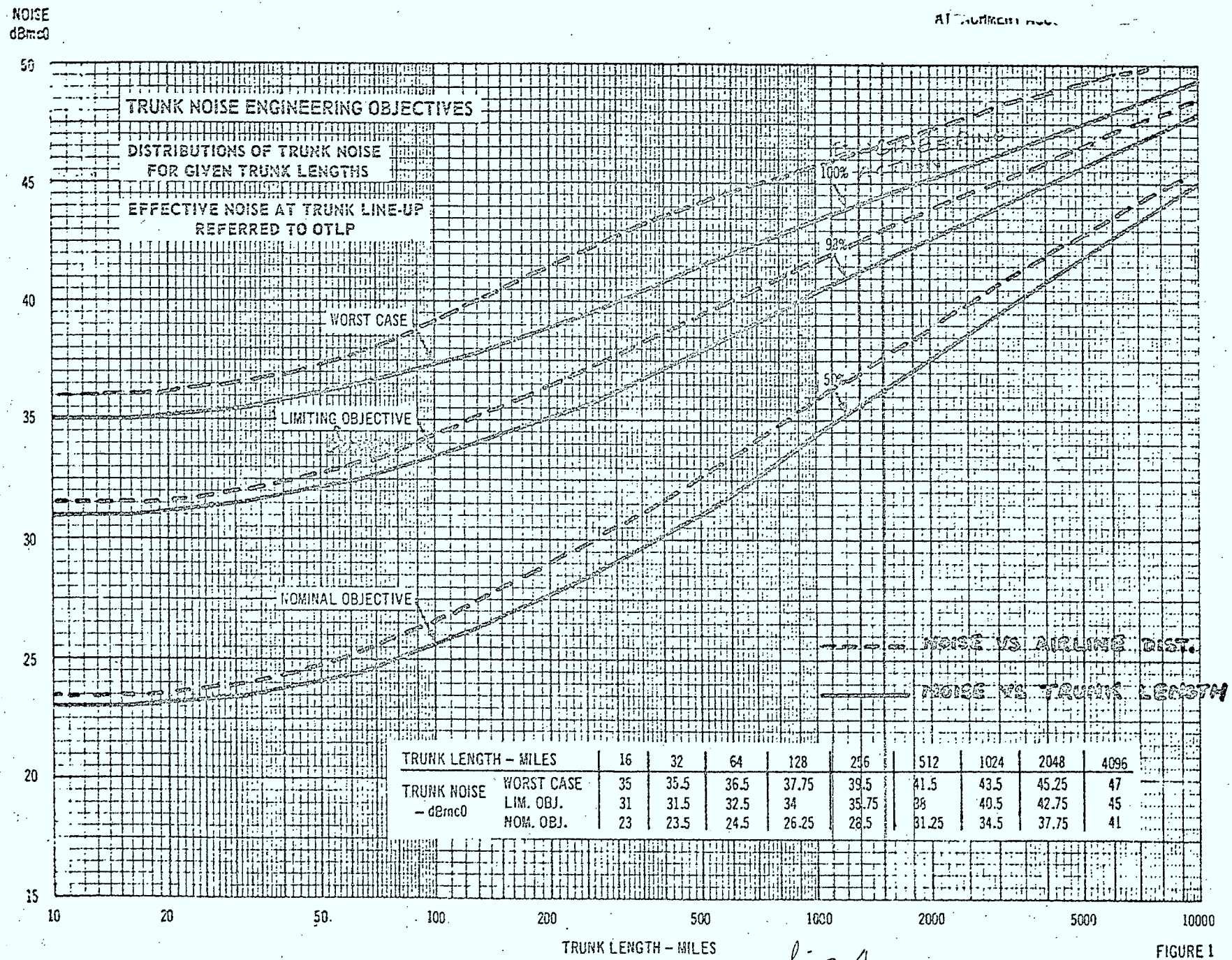
FREE SPACE LOSS = 36.6 + 20 LOG 25 + 20 LOG 7000 = 141.5 db

TYPE OF WAVEGUIDE AS IDENTIFIED BY MANUFACTURER (SEE PAGE 167) IS WR112.

LOSS OF WR112 IS 2.75/100 FEET (SEE PAGE 168).

#1

ATTACHMENT NO.



TRUNK LENGTH – MILES		16	32	64	128	256	512	1024	2048	4096
TRUNK NOISE – dBrnc0	WORST CASE	35	35.5	36.5	37.75	39.5	41.5	43.5	45.25	47
	LIM. OBJ.	31	31.5	32.5	34	35.75	38	40.5	42.75	45
	NOM. OBJ.	23	23.5	24.5	26.25	28.5	31.25	34.5	37.75	41

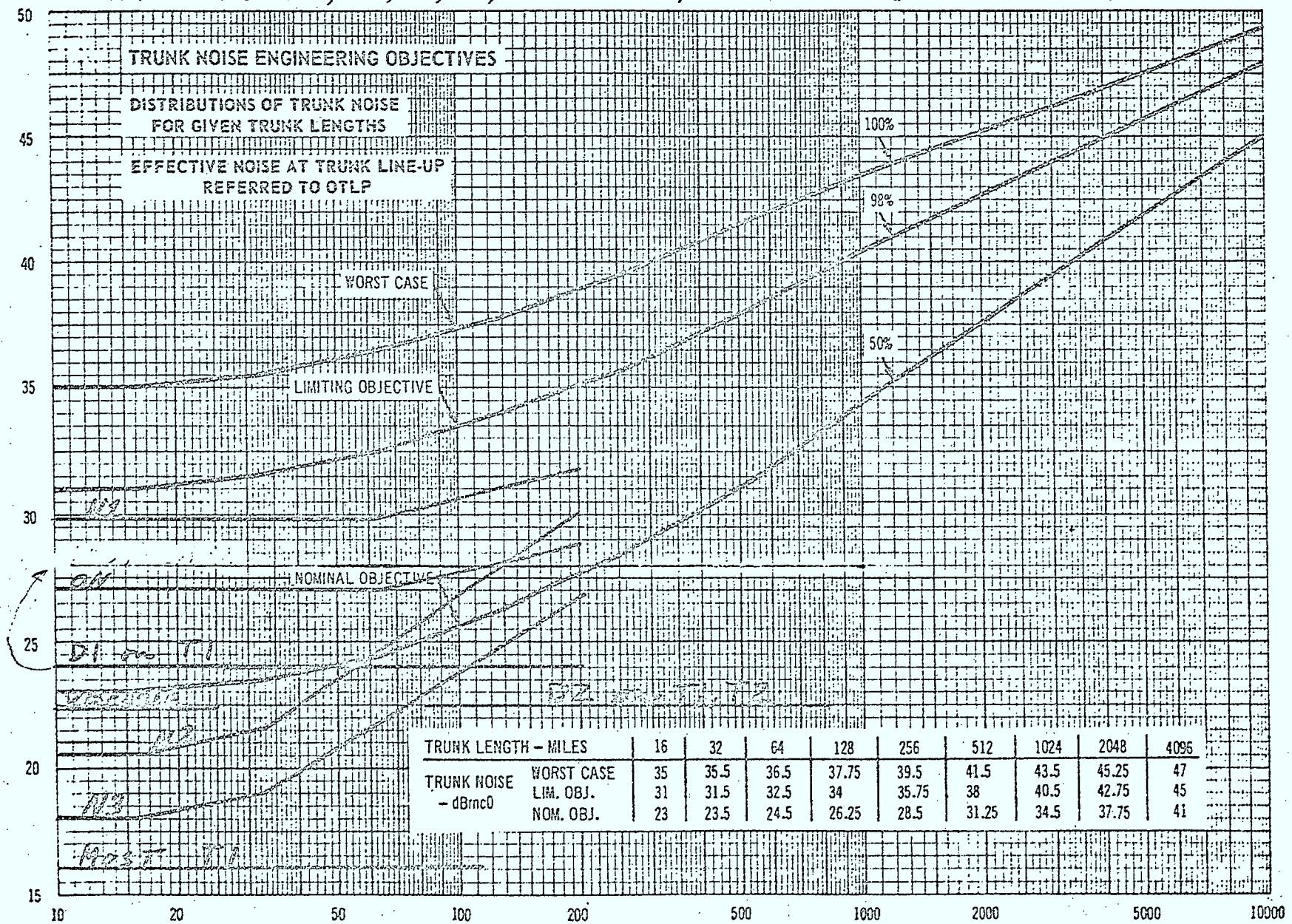
FIGURE 1

fig 4

p. 161

#2

Performance of N1, D1, OH, N2, + N3 Carrier Systems and VF Cable



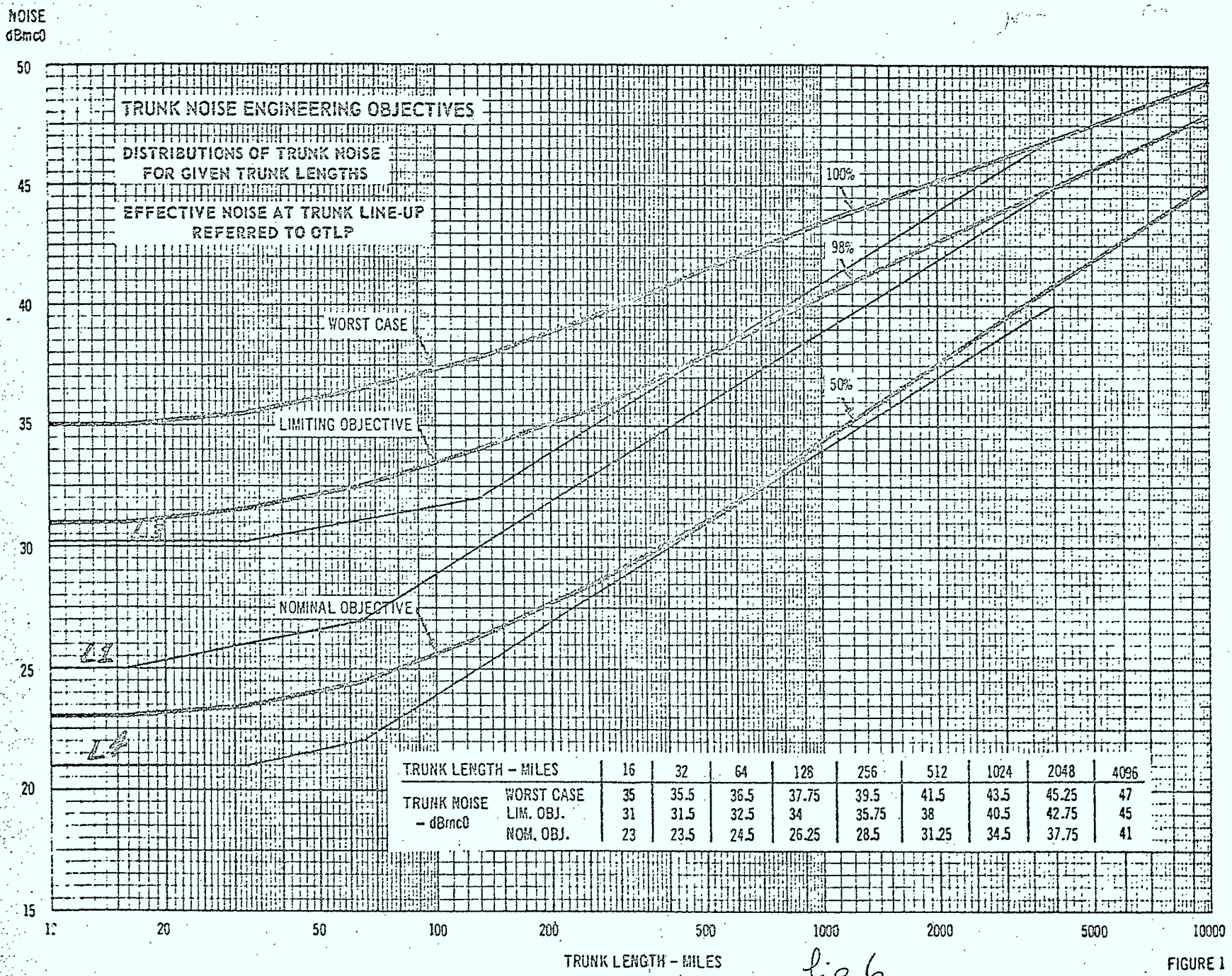
TRUNK LENGTH – MILES		16	32	64	128	256	512	1024	2048	4096
TRUNK NOISE – dBrnc0	WORST CASE	35	35.5	36.5	37.75	39.5	41.5	43.5	45.25	47
	LIM. OBJ.	31	31.5	32.5	34	35.75	38	40.5	42.75	45
	NOM. OBJ.	23	23.5	24.5	26.25	28.5	31.25	34.5	37.75	41

fig. 5

FIGURE 1

P. 162

#3

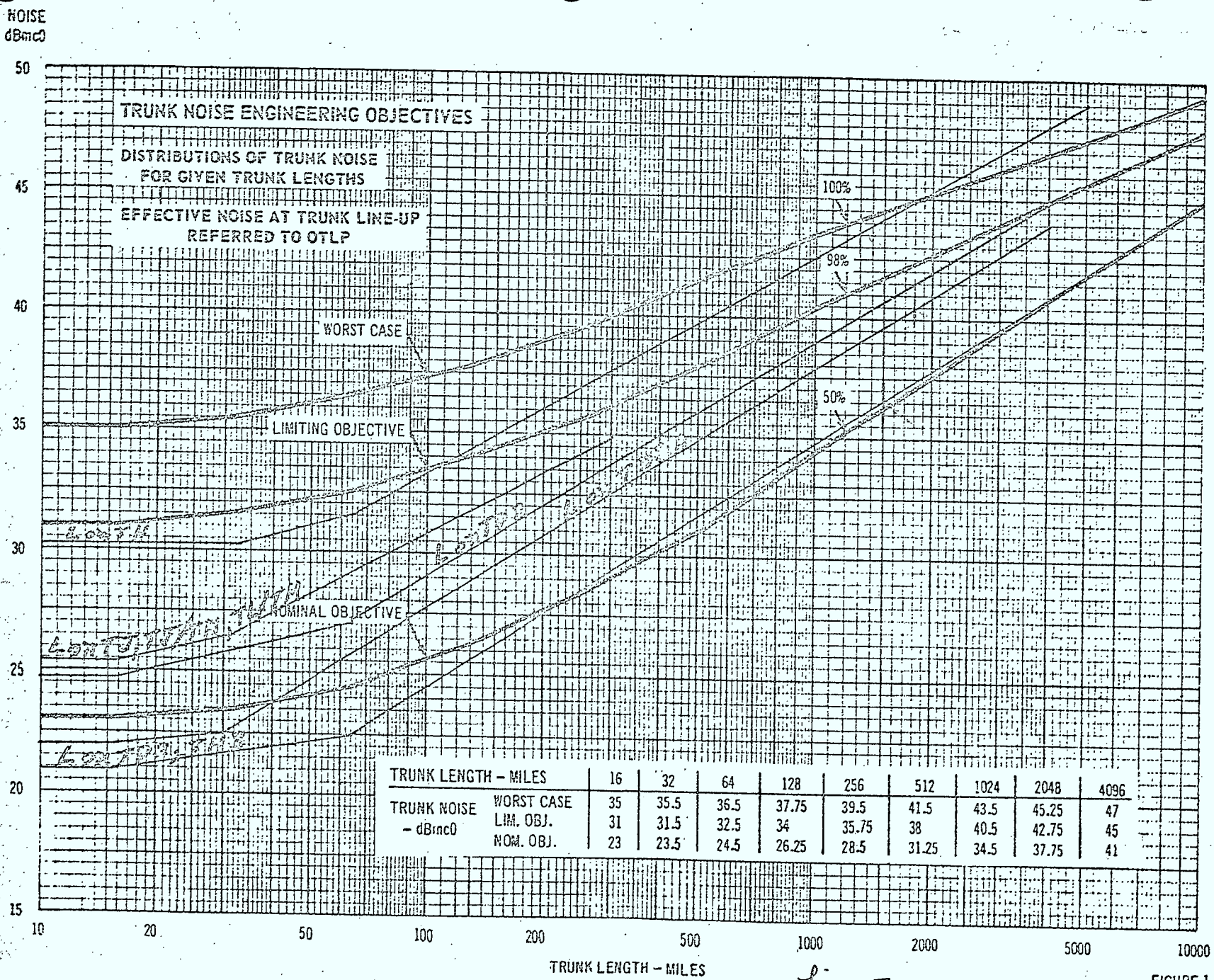


TRUNK LENGTH – MILES		16	32	64	128	256	512	1024	2048	4096
TRUNK NOISE – dBmc0	WORST CASE	35	35.5	36.5	37.75	39.5	41.5	43.5	45.25	47
	LIM. OBJ.	31	31.5	32.5	34	35.75	38	40.5	42.75	45
	NOM. OBJ.	23	23.5	24.5	26.25	28.5	31.25	34.5	37.75	41

fig 6

FIGURE 1

P.163



TRUNK LENGTH – MILES		16	32	64	128	256	512	1024	2048	4096
TRUNK NOISE – dBrnc0	WORST CASE	35	35.5	36.5	37.75	39.5	41.5	43.5	45.25	47
	LIM. OBJ.	31	31.5	32.5	34	35.75	38	40.5	42.75	45
	NOM. OBJ.	23	23.5	24.5	26.25	28.5	31.25	34.5	37.75	41

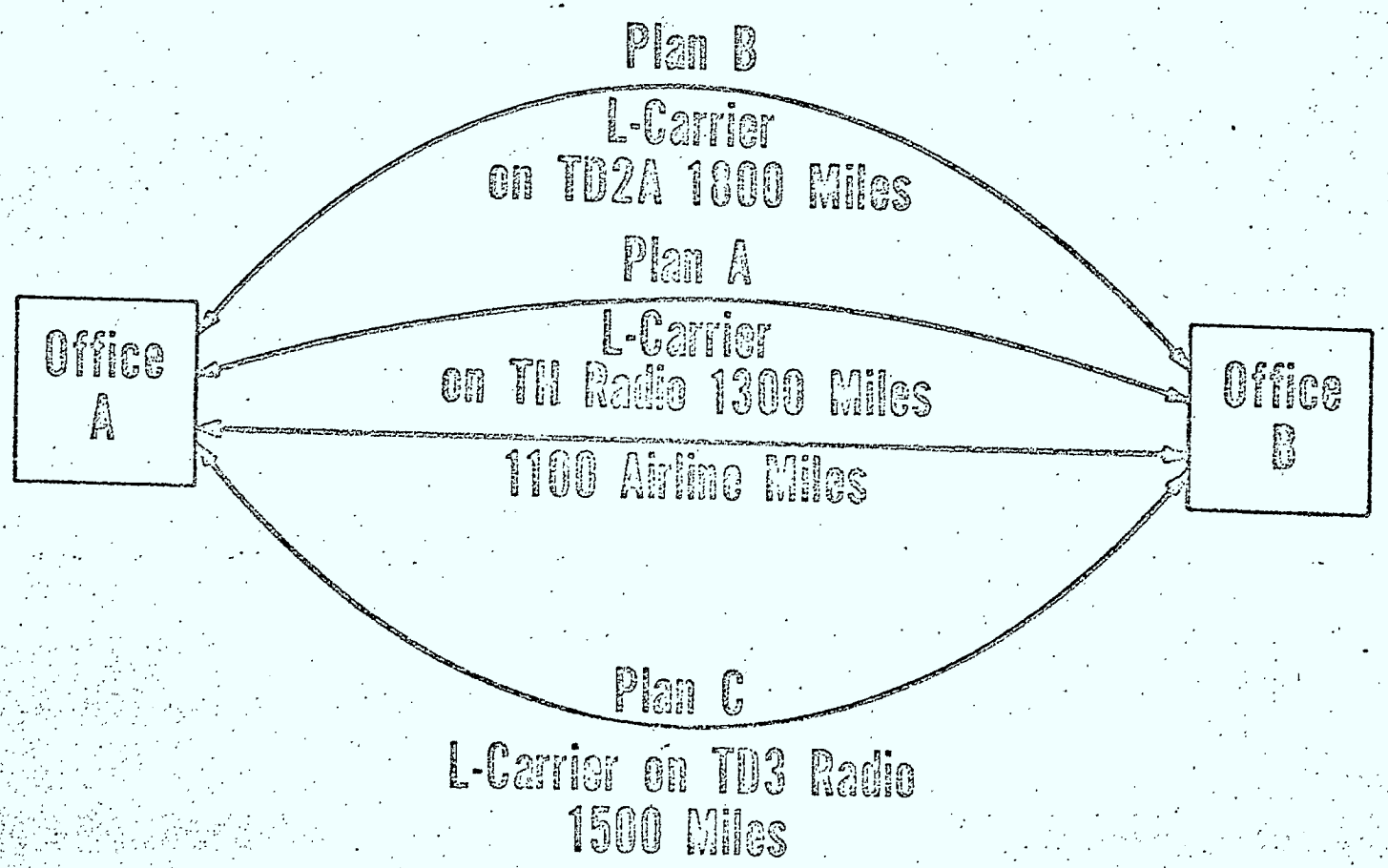
fig. 7

FIGURE 1

P. 164

Proposed System - Office A to Office B

(Plans A, B and C)



Comparison of Plans

Trunk Noise Engineering Objectives (dBrncO)	Nominal	Limiting	Worst Case
Based on Airline Distance 1100 miles	36.5	42.0	45.5
Based on Trunk Length			
Plan A-1300 miles	35.5	41.5	44.0
Plan B-1800 miles	37.0	42.5	45.0
Plan C-1500 miles	36.5	42.0	44.5
Combined Airline Dist. & Trunk Length Obj.			
Plan A	35.5	41.5	44.0
Plan B	36.5	42.0	45.0
Plan C	36.5	42.0	44.5

TECHNICAL SUMMARY

GENERAL

Frequency Range	7.125 to 7.725 GHz
Application	Medium route
Capacity	960 FDM voice circuits or television signal
Repeater Type	Heterodyne

TRANSMITTER

Power Output	500 mW nominal (input to channel branching filter)
Waveguide	WR112
IF Characteristics	
Frequency	70 MHz
Input Level	0.3 to 0.5V rms
Input Impedance	75 ohms, unbalanced
Return Loss, ± 10 MHz	30 dB
L.O. Frequency Stability	± 0.0005%

RECEIVER

Waveguide	WR112
Noise Figure	9 dB nominal
RF Input Level	−36 dBm nominal
Squelch Threshold	−76 dBm nominal
L.O. Frequency Stability	± 0.0005%
AGC Range	40 dB
IF Characteristics	
Frequency	70 MHz
3 dB Bandwidth	35 MHz
Output Impedance	75 ohms, unbalanced
Output Level	0.5 V rms nominal
Output Return Loss, ± 10 MHz	30 dB

DROP/INSERT CHARACTERISTICS

Channel Capacity	Up to 120 FDM voice circuits
Baseband Frequency Range	60 to 552 kHz
Input/Output Impedances	75 ohms, unbalanced
Input Level	−45 dBm nominal (−51 dBm min)
Output Level (with aux. amplifier)	−20 dBm nominal
Test-Tone Deviation (excl. pre-emphasis)	200 kHz rms

SERVICE CHANNEL CHARACTERISTICS

Frequency Range	300 Hz to 20 kHz
Input/Output Impedances	600 ohms, unbalanced (600 ohms balanced, optional)
Input/Output Levels	−3 dBm nominal
Test Tone Deviation	75 kHz rms

BRANCHING NETWORK CHARACTERISTICS

Waveguide	WR112
Transmit Channels	Up to four
Receive Channels	Up to four
Antenna Port VSWR	1.07 (with optional Antenna Circulator Assembly)

POWER SUPPLY CHARACTERISTICS
(−48 V SUPPLY*)

Input Voltage Range	−42 to −56 VDC
Power Consumption (Basic two-way dual channel repeater)	800 watts nominal

* 115 VAC operation optional

ENVIRONMENTAL CONDITIONS

Ambient Temperature	
Operates within specifications	0°C to +50°C
Operates with reduced performance	−30°C to +55°C
Non-operational	−54°C to +85°C
Relative Humidity	Up to 95%
Altitude	Up to 15,000 ft ASL
Shock/Vibration	As encountered in shipment

Attenuation and Power Rating

AVERAGE POWER RATINGS

HELIAX ELLIPTICAL WAVEGUIDES

Andrew Type No	Frequency, GHz	Power, kw
EW17	2.0	27.9
EW37	4.0	7.3
EW44	4.7	3.9
EW56	6.0	3.0
EW59	6.5	2.5
EW71	7.7	1.7
EW85	9.2	1.2
EW107	11.2	0.9
EW122	12.7	0.7

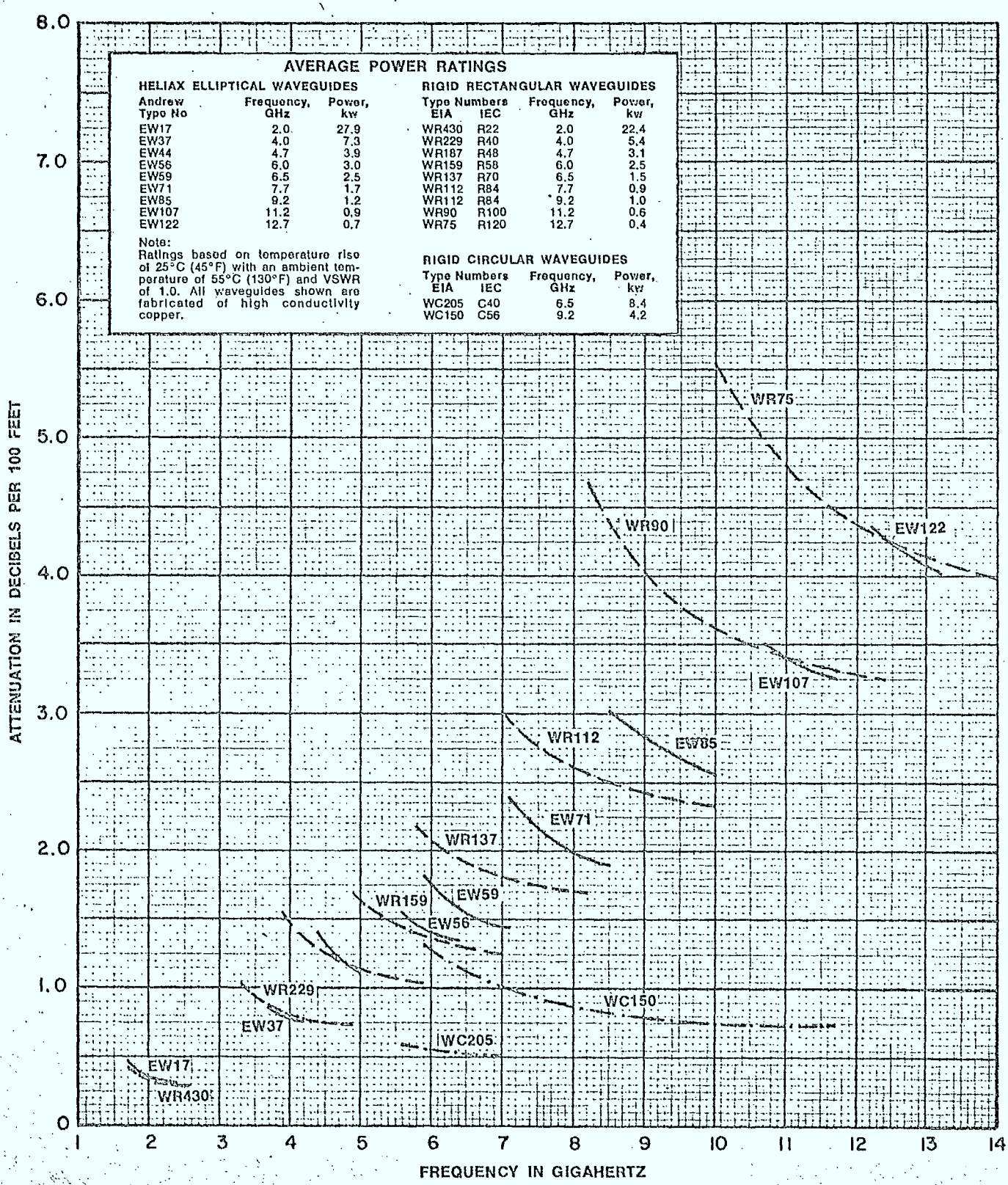
Note:
Ratings based on temperature rise of 25°C (45°F) with an ambient temperature of 55°C (130°F) and VSWR of 1.0. All waveguides shown are fabricated of high conductivity copper.

RIGID RECTANGULAR WAVEGUIDES

Type Numbers EIA	IEC	Frequency, GHz	Power, kw
WR430	R22	2.0	22.4
WR229	R40	4.0	5.4
WR187	R48	4.7	3.1
WR159	R58	6.0	2.5
WR137	R70	6.5	1.5
WR112	R84	7.7	0.9
WR112	R84	9.2	1.0
WR90	R100	11.2	0.6
WR75	R120	12.7	0.4

RIGID CIRCULAR WAVEGUIDES

Type Numbers EIA	IEC	Frequency, GHz	Power, kw
WC205	C40	6.5	8.4
WC150	C56	9.2	4.2



Attenuation curves based on:
VSWR 1.0
Ambient Temperature 24°C (75°F)

Conversion Data:
1 dB/100 feet = 3.28 dB/100 meters

TOTAL WAVEGUIDE LENGTH = 100 + 200 = 300 FT

TOTAL WAVEGUIDE LOSS = 2.75 X 3 = 8.25 db

TOTAL LOSS = 141.5 + 8.25 = 149.75 db

TRANSMIT POWER (SEE PAGE 167) = 500 mw = 10 LOG 500
= 27 dbm

TOTAL ANTENNA GAINS = 44.5 + 44.5 = 89 db

TOTAL GAIN = 89 + 27 = 116 db

POWER AT THE RECEIVER = 116 - 149.75 = -33.75 dbm

I.F. BANDWIDTH (SEE PAGE 167) = 35 MH_Z

RECEIVER NOISE FIGURE (SEE PAGE 167) = 9 db

RECEIVER NOISE LEVEL = -174 + 10 LOG 35,000,000 + 9
= - 89.56 dbm

RECEIVER THRESHOLD (SEE PAGE 167) = -76 dbm

CARRIER/NOISE = -33.75 - (-89.56) = 55.81 db

FADE MARGIN TO THRESHOLD = -33.75 -(-76) = 42.25 db

SYSTEM CAPACITY = 960 V.F. CHANNELS

HIGHEST BASEBAND FREQUENCY = 4188 KH_Z (CCIR)

TRANSMITTER PEAK DEVIATION = 4 MH_Z APPROXIMATELY

FM IMPROVEMENT = 20 LOG [4/4.188]
= -20 X .019 = -0.38 db

BANDWIDTH IMPROVEMENT = 10 LOG [(I.F.B.W.)/(2 X VF BW)]
= 10 LOG (35,000/6)
= 37.66 db

PRE-EMPHASIS IMPROVEMENT = 3.388 db
(SEE PAGE 170)

TOTAL IMPROVEMENTS = 40.668 db

CCIR EMPHASIS IMPROVEMENT

IN FRONT END THERMAL NOISE

CCIR		SLOT FREQUENCIES					
NUMBER OF CHANNELS	FREQUENCY RANGE (KHz)	70KHz	534KHz	1248KHz	2438KHz	3886KHz	5340KHz
300	60 -1300	-3.939	-2.015	3.679	-	-	-
600	60 -2660	-3.967	-3.475	-1.480	3.280	-	-
960	60 -4188	-3.973	-3.771	-2.901	-0.334	3.388	-
1200	60 -5636	-3.974	-3.862	-3.369	-1.821	0.842	3.568

THE IDEAL PRE-EMPHASIS CHARACTERISTIC IS GIVEN BY THE EXPRESSION:

$$\left.\begin{array}{l}\text{DEVIATION (RELATIVE TO}\\ \text{TEST TONE DEVIATION) (dB)}\end{array}\right] = 5-10\ \text{LOG}_{10}\left[1+\frac{6.90}{1+\frac{5.25}{\left(\frac{f_R}{f}-\frac{f}{f_R}\right)^2}}\right]\text{dB}$$

WHERE: f_R = 1.25 f_{MAX} ——— f_{MAX} IS MAXIMUM BASEBAND FREQUENCY

f = IS SLOT FREQUENCY UNDER CONSIDERATION.

CCIR RECOMMENDATION 275-1
PAGES 83-88 (1959-1966)

MULTIPLEX LOADING FACTOR IMPAIRMENT = -13 + 10 LOG (NUMBER OF CHNS.)

= -13 + 10 LOG 960

= -13 + 29.82 = 16.82 db

OVERALL IMPROVEMENT = 40.668 - 16.82 = 23.848 db

SIGNAL/NOISE = CARRIER/NOISE + OVERALL IMPROVEMENT

= 55.81 + 23.85 = 79.66 db

CHANNEL THERMAL NOISE = 88 - 79.66 = 8.34 dbrnc

INTERMODULATION NOISE GIVEN BY MANUFACTURER = 8.3 dbrnc

TOTAL RADIO NOISE = 8.34 AND 8.3 dbrnc = 11.3 dbrnc.