# SLIDE RULE INSTRUCTIONS

## I. Basic Path Equations

A. $P_r = P_o - NPL$

Where: $P_r$ = Median received r-f signal level at input to Rx preselector filter (dbm)

$P_o$ = Minimum r-f transmitter output power at output of Tx filter (dbm)

NPL = Net path loss (db)

B. $NPL = L_{\Sigma s} + L_{\Sigma f} + L_m - G_{\Sigma a} = L_p + L_{\Sigma f} + L_m$

Where: $L_{\Sigma s}$ = Sum of apparent free space losses ($L_s$) in db

$L_{\Sigma f}$ = Sum of fixed losses ($L_f$) in db

$L_m$ = Path installation and maintenance margin (db), (normally 3 db)

$G_{\Sigma a}$ = Sum of all antenna gains ($G_a$) in db

$L_p = L_{\Sigma s} - G_{\Sigma a}$

## II. Apparent Free Space Loss — $L_s$

(Relative to isotropic radiators)

$L_s = 96.58 + 20 \log d + 20 \log f$

Where: d = distance in miles

f = frequency in Gc

Slide Rule—Set $\underset{\text{set}}{\triangle}$ arrow on B scale to nominal r-f frequency of path on A scale. Move hairline to path distance on B scale. Read apparent free space loss above on $L_s$ scale.

## III. Far-Field Parabolic Antenna Gain, $G_a$ and 3-db Beamwidth, $\Theta_a$

(Relative to isotropic radiators)

A. For 55% efficient antennas (tapered illumination of aperture with edges 10-db below the center of the primary pattern).

$G_a = 7.5 + 20 \log D + 20 \log f = 44.23 - 20 \log \Theta_a$

Where: D = diameter of antenna in feet

f = frequency in Gc

Slide Rule—Set $\underset{\text{set}}{\triangle}$ arrow on B scale to nominal r-f frequency of path on A scale. Move hairline to antenna diameter on B scale. Read far-field antenna gain for 55% efficient antennas above on $G_a$ scale and average of E and H plane 3-db beamwidths on $\Theta_a$ scale.

(Note 1 — For antenna gain relative to a ½-wave dipole, subtract 2.15 db from reading on $G_a$ scale).

(Note 2 — Standard parabolic antennas above 10-gc exhibit typical efficiencies lower than 55%).

B. For antenna efficiencies other than 55%.

$AE_{(db)} = 2.6 - 10 \log \frac{100}{\%\ \text{eff}}$

Slide Rule—Set hairline to nominal r-f frequency of path on A scale. Move slide so that antenna efficiency on AE scale is under hairline. Move hairline to antenna diameter on B scale. Read far-field antenna gain above on $G_a$ scale and average of E and H plane 3-db beamwidths on $\Theta_a$ scale.

## IV. Far-Field Passive Repeater Gain — $G_p$

(Relative to isotropic radiators)

$G_p = 22.28 + 20 \log (\cos \frac{\phi}{2} A_p) + 40 \log f$

Where: $A_p$ = Area of passive repeater in square feet

$\phi$ = Included angle at passive formed by two legs of path in degrees.

f = Frequency in Gc

Passive is in far-field if:

$d_1 > \cos \frac{\phi}{2} A_p f / 2598$

Where: $d_1$ = distance in miles of shorter leg

A. To determine total passive repeater gain:

Slide Rule—Set middle index of B scale to length in feet of one side of passive on A scale. Move hairline to length in feet of other side of passive on B scale. For f less than 10 Gc, move included passive angle, $\phi_{f<10}$ at right extreme of slide, under hairline. For f greater than 10 Gc, move included passive angle, $\phi_{f>10}$ at left side of slide, under the hairline. At this instance, the end index of the slide indicates the effective area of the passive on the A scale. Move the hairline to f in Gc on the C scale. Read the passive repeater gain above on the $G_p$ scale.

B. To determine if passive is in the far-field:

Slide Rule—With the end index of the slide set to the effective area of the passive on the A scale (as in the previous calculation IVA), set hairline to f in Gc on the B scale. Move ff marker on B scale under hairline. If $d_1$ in miles exceeds reading on A scale opposite the end index of B scale, passive repeater is in far-field.

## V. Net Path Loss — NPL and $L_p$

$NPL = L_p + L_f + L_m$

Paths without passives:

$L_p = 81.59 + 20 \log d - 20 \log f - 20 \log D_1 - 20 \log D_2$

Paths with passive repeaters:

$L_p = 155.89 + 20 \log d_1 + 20 \log d - 20 \log \cos \frac{\phi}{2} A_p - 40 \log f - 40 \log D$

Where: d = path or longer leg distance in miles

$d_1$ = shorter leg distance in miles

f = frequency in Gc

D = antenna diameter in feet (55% efficiency)

SLIDE RULE INSTRUCTIONS

$\cos\frac{\phi}{2} A_p$ = effective area of passive

A. For paths without passives:

Slide Rule—Set hairline to path distance in miles on A scale. Move f in Gc on B scale under hairline. If antenna sizes are equal, move hairline to antenna diameter in feet on D scale. If antenna sizes are not equal, move hairline to the product of the antenna diameters on A scale. Under hairline, read $L_p$. Or for a predetermined $L_p$, move hairline to $L_p$. Read on A scale the minimum product of antenna diameters, or if antennas are equal in size, read on D scale the minimum diameter of antennas. For Net Path Loss, add fixed losses $L_f$ and margin loss $L_m$ to $L_p$.

B. For paths with a passive repeater:

Slide Rule—Set hairline to the distance in miles, $d_l$ of longer leg of path on scale A. Move f in Gc on C scale under hairline. (Note—For f > 10 gc, the right index of slide must be reversed with left index of slide at this point or after moving PASS ▽ marker under hairline). Move hairline to the distance in miles, $d_s$ of shorter leg of path on B scale. Move PASS ▽ marker on $L_p$ scale under hairline. For 10-foot diameter antennas, move hairline to effective area of passive on A scale and read $L_p$, or for a predetermined $L_p$, move hairline to $L_p$ and read minimum effective passive area. To determine total area of passive, $A_p$, move right index of slide under hairline, then move hairline to included angle $\phi$ and read $A_p$ on A scale. For antennas less than 10-feet in diameter after moving PASS ▽ marker under hairline, set hairline to right index of slide. Then move antenna diameter in feet on C scale under hairline and read effective passive area opposite $L_p$. For antennas greater than 10 feet in diameter, set hairline to left index of slide. Then move antenna diameter in feet on C scale under hairline and read effective passive area opposite $L_p$.

## VI. Received Carrier Power, $P_r$

$P_r$ = NPL — $P_o$

Where: $P_o$ = minimum transmitter output power in dbm.

Slide Rule—Set hairline to Tx power in dbm on $N_{dba0}$ scale and move NPL in db on $L_p$ scale under hairline. Move hairline to Pr ▽ marker on $L_p$ scale, and read $P_r$ below in dbm.

## VII. Fade Margins

A. For approximate fade margins in 3.1 kc FDM-SSB systems to a noise level of 52 dba0. (58.5 dbrnc0)

Slide Rule—Set hairline to received carrier power in dbm on $P_r$ scale. Move receiver noise figure in db on NF scale under hairline. Set hairline to highest channel or slot frequency in mc on B scale. For 25-mc receiver i-f bandwidths, under hairline read threshold correction in db on TC scale, and reduce FADE (margin) reading on $N_{dba0}$ scale under hairline by this correction to obtain the approximate fade margin in db. For channel frequencies lower than a TC correction of —6 set hairline instead on —6 on TC scale and reduce FADE (margin) reading on $N_{dba0}$ scale under hairline by 6 to obtain the approximate fade margin. For receiver i-f bandwidths other than 25-mc, note the uncorrected FADE (margin). Then set the hairline to 0 on TC scale, and move the receiver i-f bandwidth in mc on $B_{if}$ scale under hairline. Set hairline back to the uncorrected FADE (margin) on $N_{dba0}$ scale and read the approximate fade margin correction on the TC scale.

B. For approximate fade margins in video systems, calculate the following equation:

$$\text{Video Fade Margin} = 102\text{ dbm} - 10\log B_{if} - NF + P_r$$

## VIII. Theoretical Propagation Reliability

Slide Rule—Set hairline to FADE in db below median received carrier level on $N_{dba0}$ scale, and read below on $R_o$ % scale for non-diversity systems, or $R_o$ (2%) % scale for diversity systems with 2% r-f frequency separations, the Rayleigh theoretical probability of outage (below fade margin) in % of time for the worst month from multipath fading. For diversity systems with r-f frequency separations equal to or greater than 5%, square the non-diversity readings. Fade margin allowances should also be made for slow fading effects (non-multipath) when estimating overall path reliability.

## IX. FDM-SSB Circuit Noise and Signal/Noise

Noise in a multiplex channel on a microwave system in picowatts, psophometric weighting, can be determined as follows:

$$N = \Sigma N_T + H_T(N_{im_t} + N_{BI_t}) + H_R(N_{im_r} + N_{BI_r}) + \Sigma N_{echo} + \Sigma N_{IN} + N_c + N_{mux}$$

Where: $\Sigma N_T$ = sum of radio thermal noise of each path of system at highest channel or slot frequency

$H_T$ = Number of baseband r-f terminal pairs in tandem-path system

$H_R$ = Number of tandem repeaters

$N_{im}$ = Radio intermodulation noise in calculated slot

$N_{BI}$ = Radio baseband intrinsic noise in calculated slot

$\Sigma N_{echo}$ = sum of intermodulation echo noises of each antenna feeder line of all tandem paths in system.

$\Sigma N_{IN}$ = sum of r-f interference noise for each path of system.

$N_c$ = Noise contribution of baseband coupling and baseband amplifier equipment.

$N_{mux}$ = Noise contribution of multiplex equipment.

Slide Rule—Set hairline to arithmetic sum of system noise in picowatts psophometrically weighted on $N_{pwp}$ scale. Read noise in dba0 FIA weighting on $N_{dba0}$ scale, or noise in dbrnc0 on $N_{dbrnc0}$ scale, signal/noise without weighting on the S/N (unwtd) scale. In diversity systems with combiners, reduce the noise by 1 db for minimum diversity improvement.

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SLIDE RULE INSTRUCTIONS

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A. Conversion of Noise Units across 3.1 kc Bandwidth.

Model C19 Slide rules:

S/N of 88.5 db = 0 dbrnc0 = 1 pwp0 = —90 dbmp0 = —6.5 dba0 where signal/noise for C message and FIA weighting is referred to a 1000 cps test tone, and psophometric weighting is referred to a 800 cps test tone.

Model C18 Slide rules:

S/N of 87.5 db = 1 dbrnc0 = 1 pwp0 = —5.5 dba0 where signal/noise for C message, FIA, and psophometric weighting is referred to a 1000 cps test tone.

Note: Noise conversions are also commonly rounded off to:

S/N of 88 db = 0 dbrnc0 = 1 pwp0 = —6 dba0.

S/N = NPR + BWR — NLR

Where: NPR = noise power ratio

BWR = bandwidth ratio = $\frac{\text{baseband modulation bandwidth}}{\text{audio bandwidth}}$

NLR = CCIR noise load ratio = —15 + 10 log N for N $\geqq$ 240 channels or —1 +4 log N for N < 240 channels

Slide Rule—Read NLR on LF scale for number of channels on CCIR Channel Load scale.

B. To determine Thermal Noise in FDM-SSB systems:

For 3.1 kc channel bandwidths:

$$N_{dba0} = N_f - P_r - 20 \log \frac{\triangle f_{ch}}{f_{ch}} - 54.05$$

Where: $P_r$ = Received carrier power in dbm

$N_f$ = Receiver Noise Figure

$\triangle f_{ch}$ = Peak channel deviation for channel OTTL

$f_{ch}$ = Frequency of Channel (T is assumed to be 290° Kelvin)

Slide Rule—As in fade margin calculations, set hairline to received carrier power in dbm on $P_r$ scale, and move receiver noise figure in db on NF scale under hairline. (1) For channel bandwidths of 3.1 kc and OTTL channel deviations of 200 kc RMS, set hairline to channel frequency in mc on B scale, and read thermal noise in pwp below on $N_{pwp}$ scale (Note: The standard test slot frequencies of white noise test sets are marked on the B scale by arrows). (2) For channel bandwidths of 3.1 kc and OTTL channel deviations other than 200 kc RMS, set hairline to 0.2 mc on B scale, and move the RMS OTTL channel deviation in mc on B scale under hairline. Then set hairline to channel frequency in mc on B scale and read thermal noise. (3) For channel bandwidths of 3.1 kc and for a given peak r-f deviation, set hairline to CCIR channel loading and move peak r-f deviation in mc on B scale under hairline. Then move hairline to channel frequency in mc on B scale and read thermal noise. (4) To correct for other SSB channel bandwidths that are less than 10% of the channel frequency, set hairline to the channel bandwidth in kc on $B_{ch}$ scale and move 3.1 on $B_{ch}$ scale under hairline. Then set hairline to channel frequency in mc on B scale and read thermal noise.

### X. Peak r-f Deviation, $\triangle f$ (mc)

Model C19 Slide rules:

$$LF + 13 = 20 \log \frac{\triangle f}{\triangle f_{ch}}$$

Model C18 Slide rules:

$$LF + 12 = 20 \log \frac{\triangle f}{\triangle f_{ch}}$$

Where: LF = CCIR noise load ratio (load factor) in db

$\triangle f_{ch}$ = rms OTTL channel deviation in mc

Slide Rule—For OTTL channel deviations of 200 kc rms, set hairline to the number of channels on CCIR channel loading scale and read peak r-f deviation in mc above on B scale. For channel deviations other than 200 kc rms, align A and B scales. Set hairline to the number of channels on CCIR channel loading scale and move 0.2 mc on B scale under hairline. Then set hairline to the rms OTTL channel deviation in mc on B scale, and read peak r-f deviation in mc above on A scale.

### XI. Video Signal/Noise, $\frac{PTP}{RMS}$

$$\text{Video } S/N \frac{PTP}{RMS} \text{ (flat)} = 105.17 + P_r - N_f + 20 \log \triangle f$$

$$\text{Video } S/N \frac{PTP}{RMS} \text{ (Bell/EIA wtd)} = 112.17 + P_r - N_f + 20 \log \triangle f$$

$$\text{Video } S/N \frac{PTP}{RMS} \text{ (CCIR wtd)} = 115.37 + P_r - N_f + 20 \log \triangle f$$

Where: $P_r$ = Received carrier power in dbm

$N_f$ = Receiver noise figure in db

$\triangle f$ = peak r-f deviation in mc

Assumptions: Temperature is 290° Kelvin, video bandwidth is limited to 4.5 mc, and the weighting network improvement is 7 db for Bell System or EIA networks and 10.2 db for CCIR recommended networks.

Slide Rule—Set hairline to received carrier power in dbm on $P_r$ scale, and move receiver noise figure in db on NF scale under the hairline. For peak r-f deviations of 4 mc, set hairline to $\underset{\text{FLAT}}{\triangledown}$ marker and read unweighted video S/N on the video S/N $\frac{PTP}{RMS}$ (db) scale, or set the hairline to the Bell/EIA $\triangledown$ marker for Bell System or EIA weighting networks, or to the CCIR wtd $\triangledown$ marker for CCIR recommended weighting networks, and read the appropriate weighted video S/N on the Video S/N $\frac{PTP}{RMS}$ (db) scale. These readings must be corrected for baseband noise contributions. Note the number of picowatts under hairline on $N_{pwp}$ scale. Then set hairline to S/N baseband noise limit (S/N of about 72 db wtd or 68 db flat) and add the picowatts under hairline on $N_{pwp}$ scale to the picowatts

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previously noted. Set hairline to the sum of the picowatts on $N_{pwp}$ scale and read corrected video S/N on the Video $S/N\frac{PTP}{RMS}(db)$ scale. For peak deviations other than 4 mc, after setting receiver noise figure against received carrier power, set hairline to 4 mc on the B scale and move peak r-f deviation in mc on B scale under hairline. Then set hairline to appropriate marker and read video S/N on the Video $S/N\frac{PTP}{RMS}(db)$ scale.

### XII. 15-kc FM Program Channel Signal/Noise

$$S/N = 144.95 + P_r - N_f + 20 \log \frac{\triangle f}{f_{pc}}$$

Where: S/N = signal/noise in db of 15-kc FM program channel without emphasis using OTTL audio deviation of ±75 kc, not including back-to-back program channel noise.

$P_r$ = Received carrier power in dbm

$N_f$ = Receiver noise figure

$\triangle f$ = Program channel subcarrier peak deviation of microwave in mc (usually ¼ of video peak deviation)

$f_{pc}$ = Frequency in mc of program channel subcarrier

Slide Rule—Set hairline to received carrier power in dbm on P, scale and move receiver noise figure on NF scale under hairline. Set hairline to program channel subcarrier frequency in mc on B scale and move program channel peak deviation of microwave radio in mc on B scale under hairline. Set the hairline to the $\frac{FM - S/N}{\nabla}$ marker (at left index of slide) and read program channel S/N on S/N (unwtd) scale. Add 10 db to this reading for standard 75-microsecond pre-emphasis improvement. This answer must be corrected for IM noise and back-to-back program channel noise which places a limit at an S/N of approximately 72 db or higher. Read picowatts on the $N_{pwp}$ scale opposite the S/N calculated value (including emphasis improvement) and the S/N limit value. Convert the sum of the picowatts on the $N_{pwp}$ scale back to S/N on the S/N (unwtd) scale for corrected program channel signal/noise.

### XIII. Wavelength in Free Space

$$\lambda = \frac{11.808}{f}$$

Where: $\lambda$ = Wavelength in inches

f = frequency in gc.

Slide Rule—Set hairline to λ marker on D scale. Move f in gc on C scale under hairline and read wavelength in inches on D scale under index of slide.

### XIV. Fresnel Zone

$$R_f = 72.1 \sqrt{\frac{d_i (d - d_i)}{fd}}$$

Where: $R_f$ = radius of first Fresnel Zone in feet

d = total path length in miles

$d_i$ = shortest distance from end of path to obstruction in miles

f = frequency in gc

Slide Rule—Set hairline to path length in miles on A scale, and move frequency in gc on B scale under hairline. Set hairline to $\frac{1.0\ FZ}{\nabla}$ marker for full first Fresnel Zone radius, to $\frac{0.6\ FZ}{\nabla}$ marker for 0.6 first Fresnel Zone radius, to $\frac{0.5\ FZ}{\nabla}$ marker for 0.5 first Fresnel Zone radius, or to $\frac{0.3\ FZ}{\nabla}$ for 0.3 first Fresnel Zone radius. Under hairline, read mid-point Fresnel Zone radius clearance required in feet on D scale (multiply D scale reading by 10). For obstructions not at midpoint of path, move the fraction of path, $\frac{d_i}{d}$, on $d_i/d$ scale under hairline, and read the Fresnel Zone clearance requirements on D scale opposite left index of slide.

### XV. Earth Curvature

$$h = \frac{2 d_k^2}{3 K}$$

Where: h = elevation of terminal antenna in feet required above obstacle elevation for line-of-sight clearance of earth curvature determined by tangential ray at obstacle.

$d_k$ = distance in miles from terminal to obstacle.

K = earth radius factor (normally calculations are made for K = 1 and 0.6 first Fresnel Zone radius)

Slide Rule—Set $\underset{1st}{\triangle}$ marker on B scale opposite K factor on A scale. Move hairline to distance, $d_k$, in miles on D scale from obstacle to end of path. Read elevation in feet above on B scale required at end of path above the elevation of obstacle. Add Fresnel Zone clearance requirements for line-of-sight clearance. When $d_k$ is between 10 and 100 miles, multiply B scale reading by 100. This calculation must be made for each portion of the path from obstacle. Tower heights are determined from the required line-of-sight plus Fresnel Zone elevations less actual ground elevations. These heights can be adjusted by the ratio of the distances of each portion of the path. To equalize tower heights, multiply the fraction of the path ($\frac{d_k}{d}$) times the difference in tower heights, and correct the tower height for this end of the path by this result.

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SLIDE RULE INSTRUCTIONS

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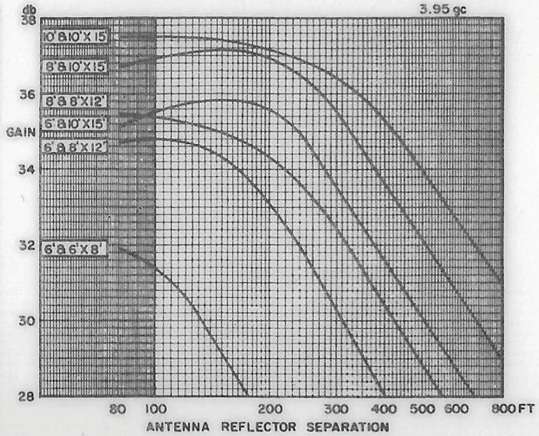


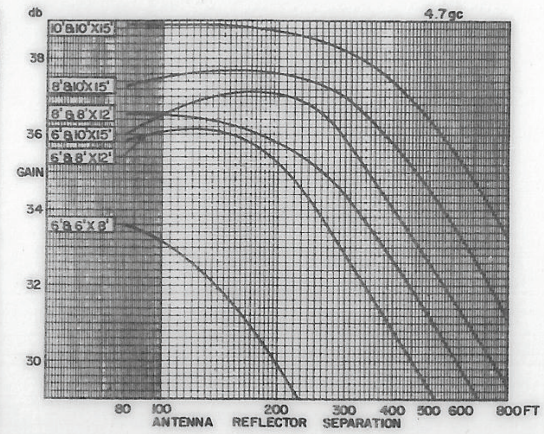


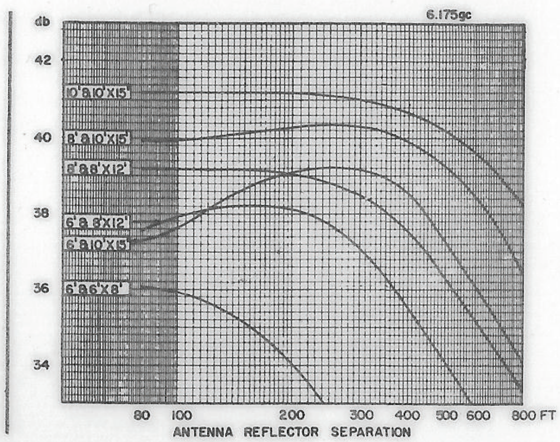


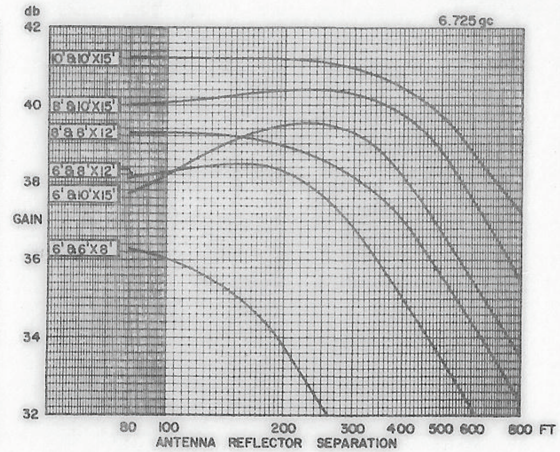


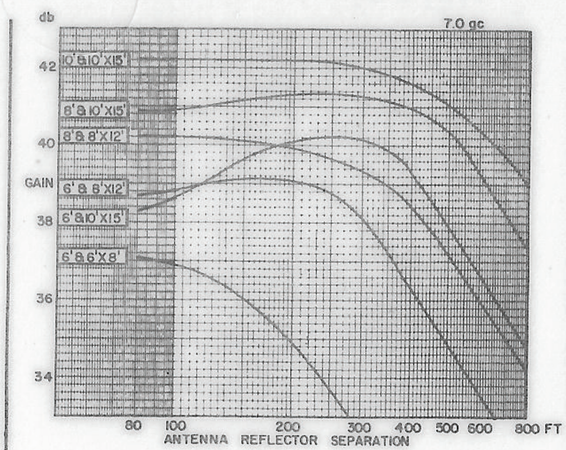


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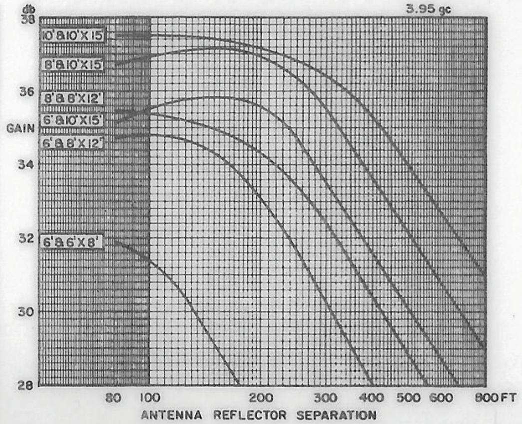


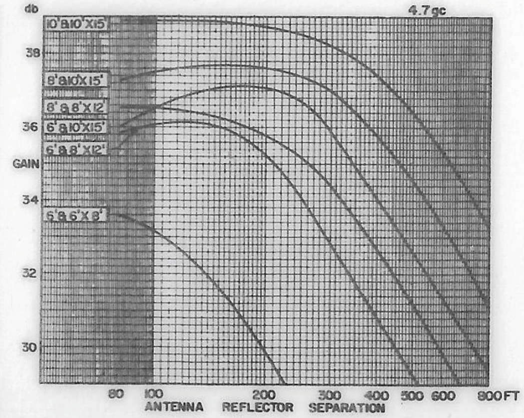


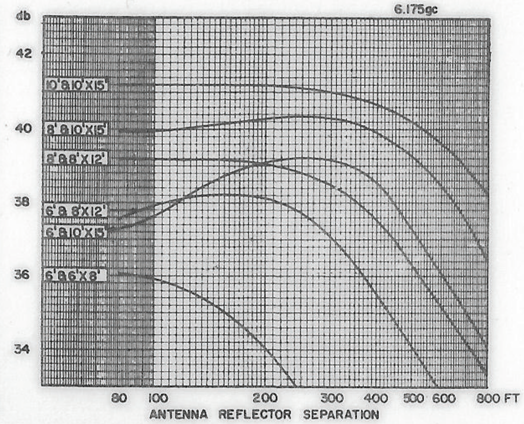


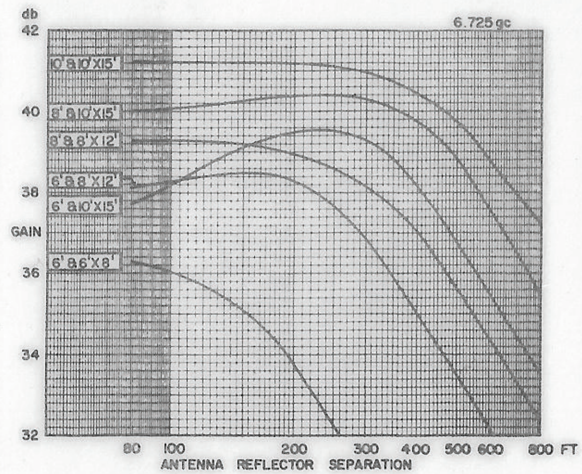


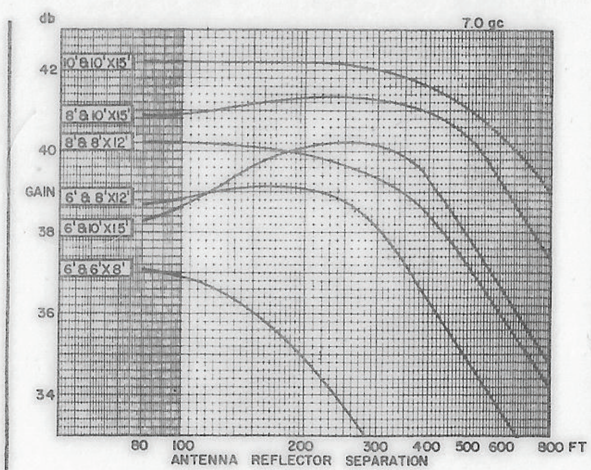


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FIXED LOSSES

## Fixed Losses

| | |
|---|---|
| ⅞″ Coaxial Air Dielectric-Flexible | 1.8 db per 100′ at 2-gc |
| 1⅝″ Coaxial Air Dielectric-Flexible | 1.1 db per 100′ at 2-gc |

Flexible rectangular waveguide: Multiply equivalent rigid rectangular losses in db by 5.

| | 10.5-gc | 11-gc | 12-gc | 13-gc | 15-gc |
|---|---|---|---|---|---|
| Rectangular waveguide RG-75 loss per 100′ | 5.3 db | 5.0 db | 4.6 db | 4.4 db | 4.2 db |
| Heliax waveguide EW-107 loss per 100′ | 3.6 db | 3.4 db | 3.2 db | — | — |

| | 3.7 - 5.0 gc | 6 - 8 gc | 10 - 13 gc |
|---|---|---|---|
| 4 & 6 Foot Radome Loss | 0.4 db | 0.55 db | 1.2 db |
| 8 Foot Radome Loss | 0.4 db | 0.60 db | 1.2 db |
| 10 Foot Radome Loss | 0.6 db | 0.8 db | 1.5 db |
| Hyperlon Radome Loss for Shrouded Antennas | 0.1 db | 0.1 db | 0.2 db |
| Circulator Forward Loss Between Ports | 0.5 db | 0.5 db | 0.5 db |

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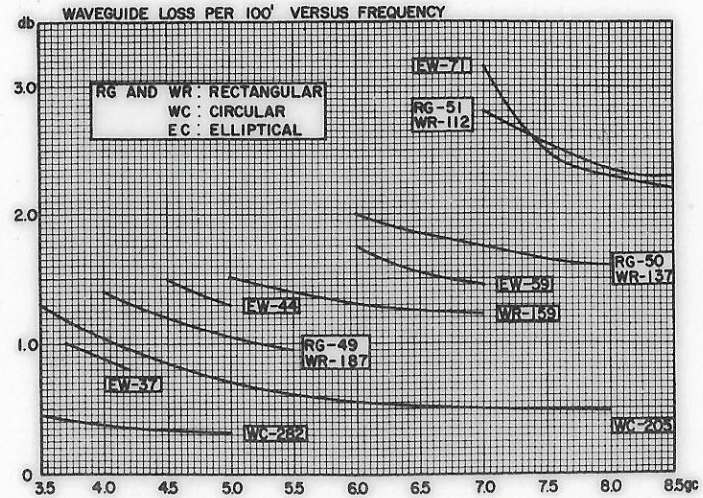


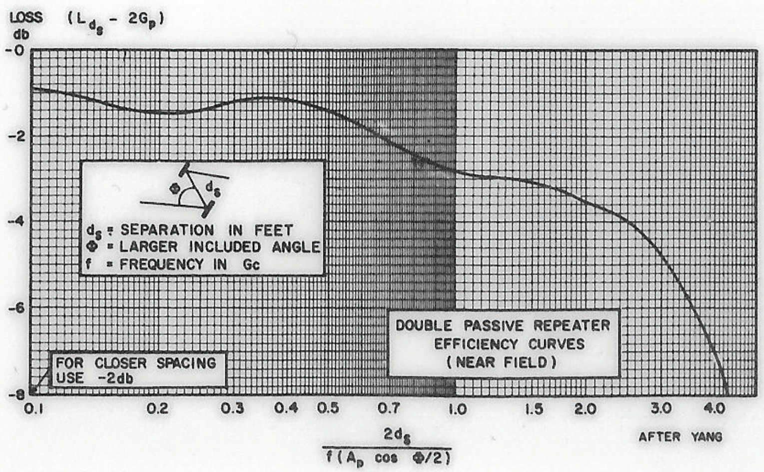


## FDM-SSB NOISE MEASUREMENT FREQUENCIES

| No. of Channels | Band Limits | | In-Band Slots | | |
|---|---|---|---|---|---|
| | High Pass | Low Pass | Lower | Center | Upper |
| 24 | 12 kc | 108 kc | 40 kc | 70 kc | 105 kc |
| 60 | 12 kc | 252 kc | 40 kc | 185 kc | 245 kc |
| 60 | 60 kc | 300 kc | 70 kc | 185 kc | 270 kc |
| 120 | 60 kc | 552 kc | 70 kc | 270 kc | 534 kc |
| 240 | 60 kc | 1,052 kc | 70 kc | 534 kc | 1,002 kc |
| 300 | 60 kc | 1,300 kc | 70 kc | 534 kc | 1,248 kc |
| 600 | 60 kc | 2,660 kc* | 70 kc | 1,248 kc | 2,438 kc |
| 960 | 60 kc | 4,028 kc | 70 kc | 2,438 kc | 3,886 kc |
| 960 | 316 kc | 4,188 kc | 534 kc | 2,438 kc | 3,886 kc |
| 1,200 | 316 kc | 5,564 kc | 534 kc | 3,886 kc | 5,340 kc |
| 1,800 | 316 kc | 8,204 kc | 534 kc | 3,886 kc | 8,002 kc |
| 2,700 | 316 kc | 12,388 kc | 534 kc | 3,886 kc | 12,150 kc |

*Note — Highest modulation frequency for 600 channels is 2540 kc in CCITT systems and 2788 kc in WECO L-600 systems.

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FIXED LOSSES

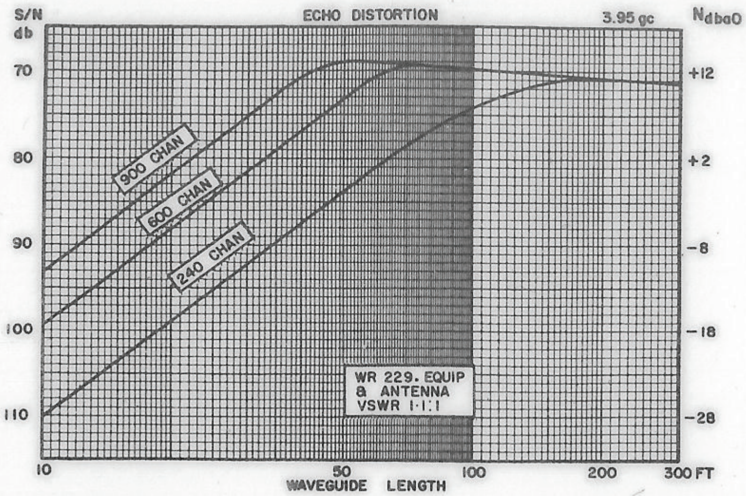
ECHO DISTORTION

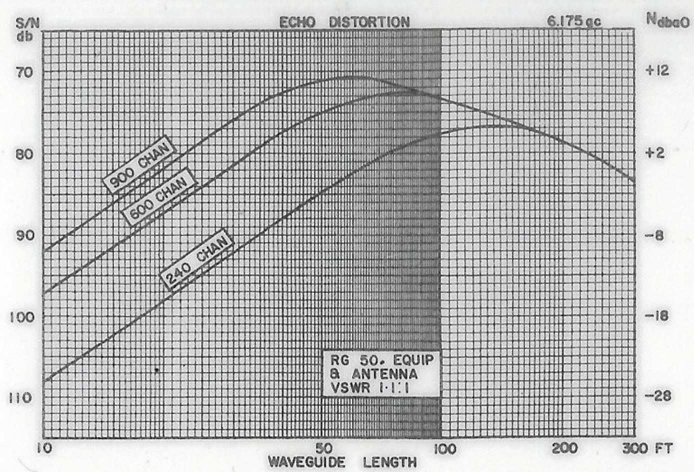
### Echo Distortion

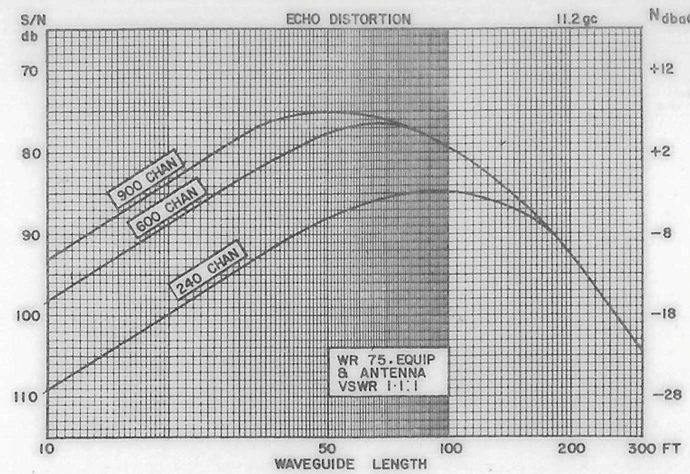
Echo distortion curves are in db, S/N flat weighted and noise, dbaO. To convert for other feeder losses, use waveguide loss chart to determine differences in feeder loss from the waveguide used in the curve (multiply by two to allow for complete travel of echo signal). If the feeder loss is lower, add this difference to the echo noise of the curve. If the feeder loss is higher, subtract this difference from the echo noise of curve.

Echo curves are based on antenna and equipment VSWR's of 1.1:1. For other VSWR's, add or subtract the following corrections:

| | | | |
|---|---|---|---|
| Equipment VSWR | 1.05:1 | 1.05:1 | 2:1 |
| Antenna VSWR | 1.1:1 | 1.15:1 | 1.15:1 |
| Correction Factor | —6 db | —3 db | +22 db |




ECHO DISTORTION