ESN NO. 3

WORLD WIDE SUPPLIERS OF ELECTRONIC COMMUNICATIONS EQUIPMENT

ENGINEERING SERVICE NOTES

EQUIPMENT MODEL A Discussion Concerning Relative and Absolute Levels of Intelligence, Carrier and Intermodulation Distortion Products in an SSB System. DATE

1. This discussion is intended to point out the differences between measurements made with respect to tone or average power, and measurements made with respect to peak envelope power. To avoid confusion in such measurements, a definite delineation of the reference level should be made, and all other levels should be referred to the selected reference level.

2. Consider the two specifications listed below; these specifications refer to the measurement of third order intermodulation distortion.

a) SPECIFICATION #1:

"third order intermodulation products shall be down at least -35 db from either tone of a standard two tone test with the transmitter operating at rated PEP."

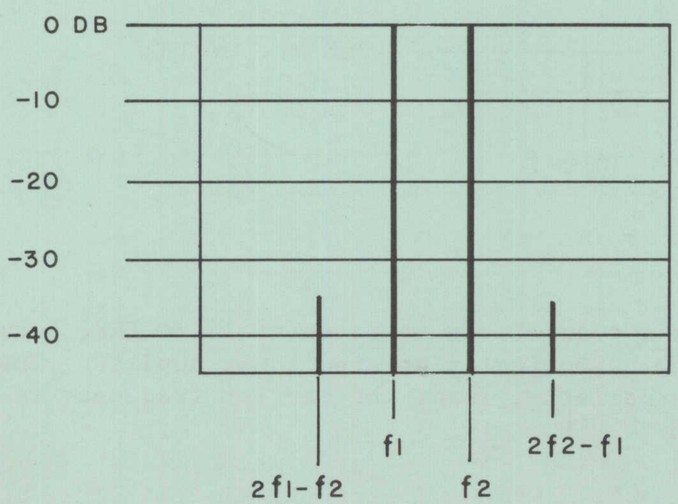
b) SPECIFICATION #2:

"third order intermodulation products shall be down at least -41 db from rated PEP, using a standard two tone test".

These specifications say the same thing, even though there is a 6 db difference in the results. The second specification is the more preferable, since it projects a better "image" for the equipment, and, also, reflects current practice.

3. Figure #1 below, shows the spectrum analyzer presentation of two equal amplitude, harmonically related tones at an RF frequency; the output of an SSB transmitter is being monitored at a 50 ohm resistive load. Average power devices indicate that the average power is 5 kw; thus, with two tones, PEP is 10 kw.

FIGURE 1



P AVE = 5 KW

PEP = 10 KW

P EACH TONE = 2.5 KW

INTERMOD = 35 DB DOWN FROM EITHER TONE

Figure #1, then, shows the 3rd order intermodulation products down 35 db from either tone. This would correspond to the measurement called for in specification #1.

4. Since the total average power is 5 kilowatts, and this power is equally divided between the two desired tones f-1 and f-2, each tone represents an average power of 2.5 kilowatts. Thus: THE 0 DB LINE OF FIGURE #1 ACTUALLY REPRESENTS AN ABSOLUTE POWER LEVEL OF 2.5 kilowatts.

Since: $DB = 10 \log \frac{P^1}{P^2}$

Then: 2.5 kw (or 0 db) on the analyzer screen is:

$10 \log \frac{1 \times 10^4}{2.5 \times 10^3}$ or $10 \times .6$ or -6 db

down from PEP, which is 10 kilowatts.
Thus: if specification #2 is used, the third order distortion is down 35 plus 6 or 41 db down from PEAK ENVELOPE POWER.

5. It might be argued that some of the 5 kilowatts of average power is being dissipated by the 3rd order distortion tones; however, the power in these tones is so small that it may be neglected. The power in one of the 3rd order tones is:

$-35 = 10 \log \frac{2.5 \text{ KW}}{P \text{ Intermod}}$ then: $3.5 = \log \frac{2.5 \text{ kw}}{P \text{ intermod}}$

then: $3.16 \times 10^3 = \frac{2.5 \text{ kw}}{P \text{ intermod}}$ then: $P \text{ intermod} = \frac{2.5 \times 10^3}{3.16 \times 10^3}$

or 795 milliwatts. Total power expended in the two 3rd order tones is 2 x 795 milliwatts, or 1.590 watts. These relationships are shown below, in Figure #2:

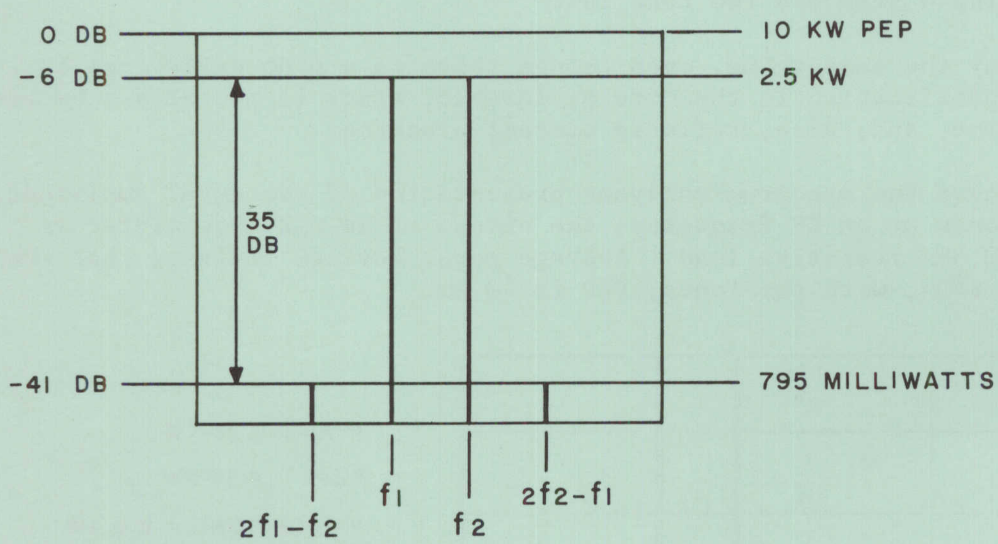


FIGURE 2

6. Consider, now, a case where a transmitter is rated at 10 kw PEP, 5 kw average power, with two equal amplitude, harmonically related tones applied. The transmitter is to be operated into a 50 ohm resistive load; the carrier frequency is to be re-inserted at -20 db with respect to PEP.

a) PEV (peak envelope voltage corresponding to 10 kw PEP):

$$PEV = \sqrt{PEP\ Z} = \sqrt{1 \times 10^4 \times 5 \times 10^1} = \sqrt{50 \times 10^4} = 707 \text{ volts.}$$

b) Pc (carrier power) with respect to PEP:

$$20 = 10 \log \frac{PEP}{Pc} \qquad \text{then:} \qquad 2 = \log \frac{PEP}{Pc}$$

$$100 = \frac{PEP}{Pc} \qquad \text{therefore:} \qquad Pc = \frac{PEP}{100} = 100 \text{ watts}$$

c) Ec (carrier voltage):

$$Ec = \sqrt{Pc\ Z} = \sqrt{1 \times 10^2 \times 5 \times 10^1} = \sqrt{50 \times 10^2} = 70.7 \text{ volts.}$$

d) Et (voltage of one tone):

$$Et = \frac{PEV - Ec}{2} = \frac{707 - 70.7}{2} \cong 318 \text{ volts.}$$

e) Pt (power in one tone):

$$Pt = \frac{Et^2}{Z} = \frac{(3.18 \times 10^2)^2}{50} = \frac{10.1 \times 10^4}{50} = 2.02 \text{ kw}$$

f) Pav (total average power):

$$Pav = Pt1 + Pt2 + Pc = 2.02 \text{ kw} + 2.02 \text{ kw} + 100 \text{ watts} = 4.14 \text{ kw}$$

g) DB relationship of Pt1 = Pt2 to PEP:

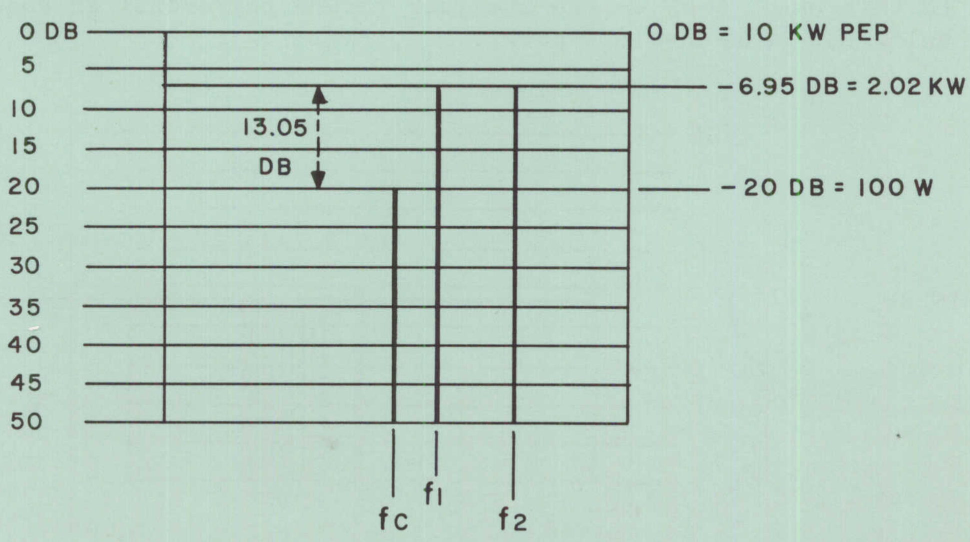
$$DB = 10 \log \frac{PEP}{Pt} = 10 \log \frac{1 \times 10^4}{2.02 \times 10^3} = 10 \times \log 4.95 = 10 \times .695 = 6.95 \text{ db.}$$

h) DB relationship of Pt1 = Pt2 to Pc:

$$DB = 10 \log \frac{Pt1}{Pc} = 10 \log \frac{2.02 \times 10^3}{100} = 10 \times 1.305 = 13.05 \text{ db}$$

i) Figure #3, below, shows the spectrum analyzer presentation of this condition.

FIGURE 3



7. Now consider a case where the transmitter of paragraph 6 is to operate with ten equal amplitude, harmonically related tones and a suppressed carrier of -20DB (with respect to PEP.)

a) PEV (peak envelope voltage) is 707 volts, as before.

b) Pc (carrier power) is 100 watts, as before.

c) Ec (carrier voltage) is 70.7 volts, as before.

d) Et (voltage of <u>one</u> tone):

$$Et = \frac{PEV - Ec}{10} = \frac{636.3}{10} = 63.6 \text{ volts.}$$

e) Pt (power in <u>one</u> tone):

$$Pt = \frac{Et^2}{Z} = \frac{(6.36 \times 10^1)^2}{50} = \frac{40.5 \times 10^2}{5 \times 10} = 8.1 \times 10 = 81 \text{ watts}$$

f) Pav (total average power):

Pav = N x Pt + Pc = 910 watts (N= number of tones)

g) DB relationship of Pt to PEP:

$$DB = 10 \log \frac{PEP}{Pt} = 10 \log \frac{1 \times 10^4}{81} = 10 \log 1.235 \times 10^2$$

$$DB = 10 \times 2.092 = 20.92 \text{ DB}$$

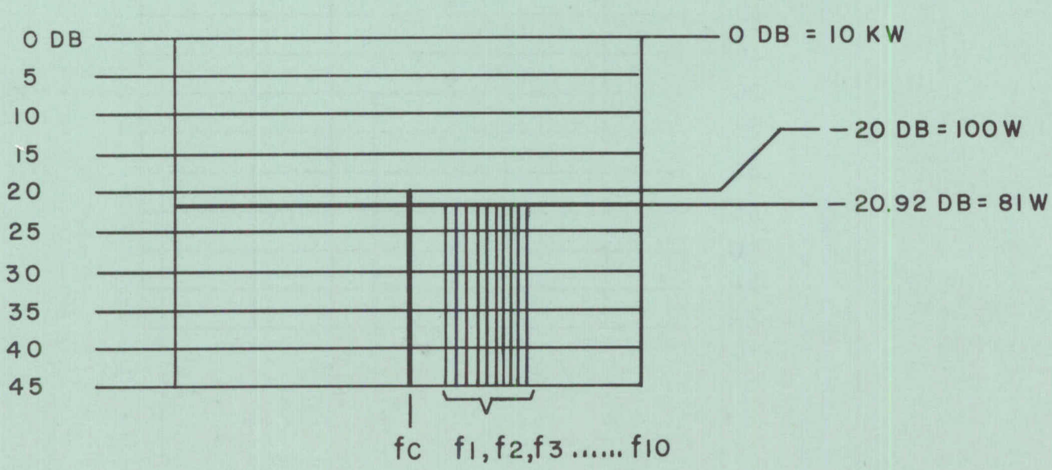
h) DB relationship of Pt to Pc:

$$DB = 10 \log \frac{Pc}{Pt} = 10 \log \frac{100}{81} = 10 \log 1.235$$

$$DB = 10 \times .092 = .92 \text{ DB}$$

i) Figure 4, below, shows the spectrum analyzer display of these relationships. Figure 5 shows the same display when the gain and attenuator controls on the analyzer are adjusted to present the point of highest amplitude, (Fc), at 0 DB on the analyzer screen.
In this case, 0 DB on the analyzer screen represents an absolute power -20 DB below the peak envelope power.

FIGURE 4



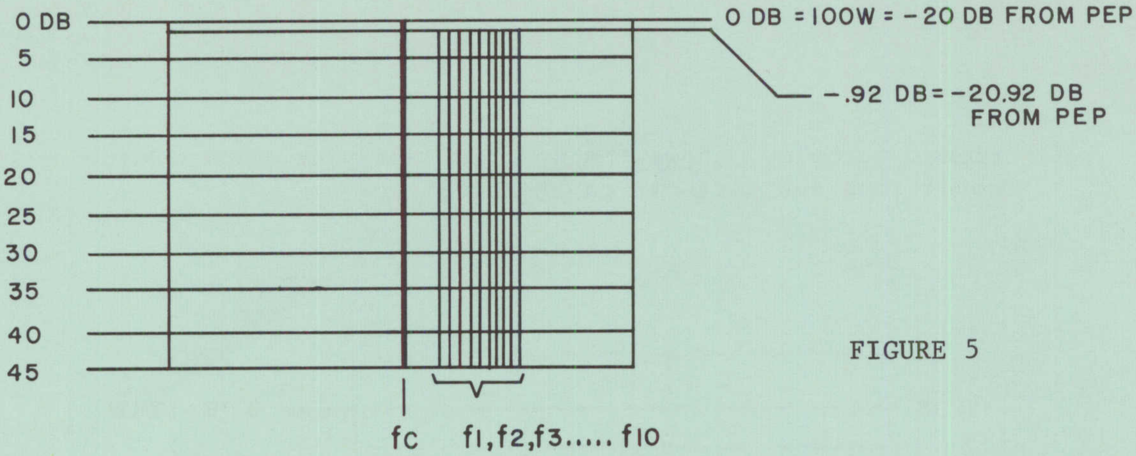


FIGURE 5

8. The conditions described in the previous example represent, probably, the maximum degradation of average power to be expected in an SSB system under conventional teletype tone or voice modulation conditions. Generally, as a rule of thumb, for practical intelligence modulation, average power will equal from .1 to .2 times peak envelope power, because the individual tones at any instant are not of equal amplitude nor harmonically related. Thus, as the number of random intelligence frequencies is increased, the probability becomes less that these frequencies will add vectorally to produce a peak envelope voltage which is the sum of the individual random voltages.
As a practical example, consider the case of the TMC Model GPT-40K transmitter. This device is rated at 40 KW PEP, 20 KW average power, with two equal amplitude, harmonically related tones applied, and with third order intermodulation distortion down -41 DB from PEP. When this transmitter is modulated with ten equal amplitude, harmonically related tones, and operated at 40 KW PEP, average power is close to 4 KW, that is, .1 PEP. When this transmitter is operated with two independent voice channels and carrier at -20 DB in an independent sideband configuration, at 40 KW PEP, average power can be increased to approximately 10 KW or more, without appreciable distortion. If a certain amount of distortion can be tolerated, average power may be increased to as high as 15 KW. If signal processing techniques, such as preemphasis, clipping, compression and frequency compression are practiced, the average to peak power ratio may be increased even more.

9. Let us assume that the 10 KW PEP transmitter of paragraph 6 is operated in the Independent Sideband mode, with two separate voice channels and a carrier reduced -20 DB with respect to peak envelope power. It will be assumed that Pav / PEP is .25; thus, total average power will be 2.5 KW.

a) PEP= 10 KW

b) Pav = 2.5 KW

c) Pc = 100 watts = -20 DB with respect to 10 KW

d) The power in each intelligence channel will be:

$$\frac{Pav - Pc}{2} = \frac{2500 - 100}{2} = 1200 \text{ watts}$$

e) the total average power in a voice channel is 1200 watts, but this power is spread over approximately 3,000 cps of spectrum; if we assume that the average number of audio tones per channel is 120, each dissipating 10 watts, then the average power level in each channel is 10 watts. These assumptions are admittedly empirical, because of the random nature of the intelligence.

f) Figure 6, below, shows the spectrum analyzer presentation of the conditions set forth in paragraph 9.

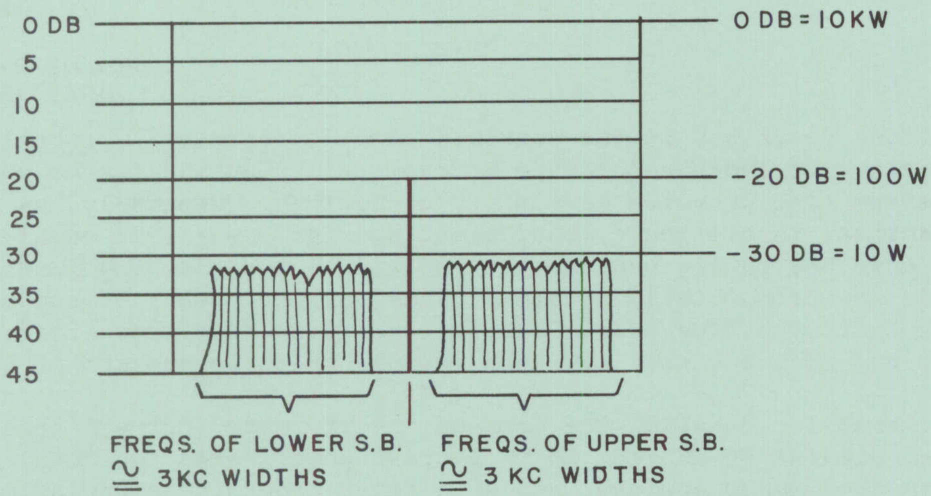


FIGURE 6

Note that the average intelligence power level, 10 watts, is -10DB with respect to the carrier level, 100 watts, and -30 DB with resepct to peak envelope power.

g) a common fault in carrier reinsertion technique is to suppress the carrier -20 DB (or other stipulated value) with respect to the average intelligence levels. In the situation of Figure 6, this would place the carrier at -20 DB with respect to 10 watts, or at .1 watt. Thus, the carrier suppression with respect to PEP would be:

$$DB = 10 \log \frac{PEP}{Pc} = 10 \log \frac{1 \times 10^4}{.1} = 10 \log 1 \times 10^5 = \underline{50\ DB.}$$

10. The average to peak power ratio of an SSB system can be greatly improved by the judicious use of the ALDC (Automatic Load and Drive Control) feature, which is incorporated in most SSB systems. The simplified schematic of such a system is shown in Figure 7, below.

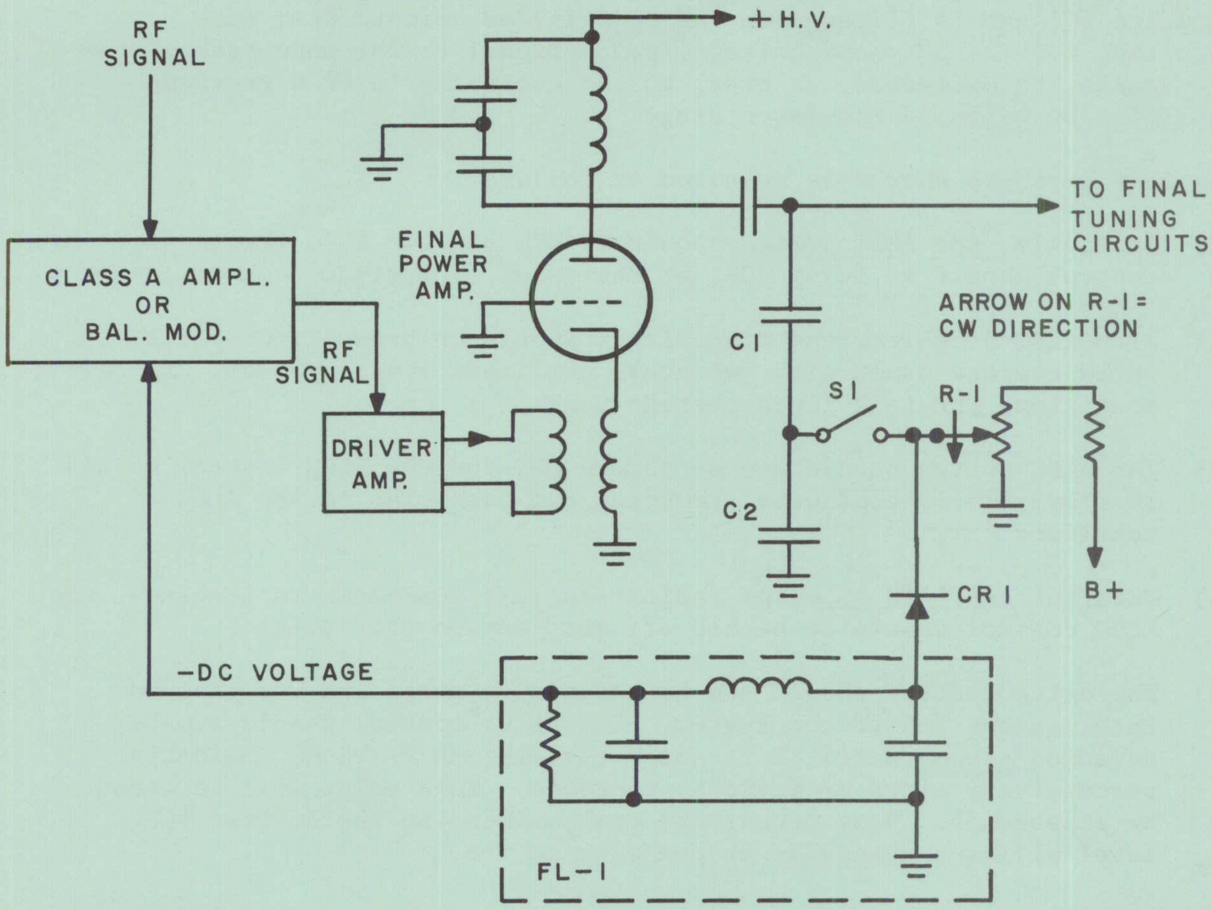


FIGURE 7

a) C1 and C2 form a capacitive voltage divider; the divider samples the RF voltage at the plate of the final amplifier, and delivers the sample to the cathode of the ALDC diode, CR1.

b) R1 is the ALDC threshold control, which varies the back bias on CR1. With R1 fully CCW, a high positive voltage holds CR1 cutoff; this back bias exceeds the peak voltage of the RF sample from the amplifier plate.

c) Switch S1 is the ALDC ON - OFF switch; in the OFF position, the RF sample is removed from CR1.

d) When the peak voltage of the RF sample exceeds the back bias on CR1, the diode conducts, and the RF sample is rectified. The resultant negative voltage is filtered in low pass filter network FL1; the resultant pure negative DC voltage, proportional to the magnitude of the RF sample, is delivered, as bias, to the control grid of a previous amplifier or balanced modulator stage.

e) The ALDC circuits should be adjusted as follows:

(1) Initially, the ALDC switch should be OFF and the ALDC threshold control should be fully CCW, at the point of maximum back bias.

(2) With ALDC disabled, the transmitter should be brought up to its rated average power with two equal amplitude tones applied. In this condition, PEP is 2 times average power.

(3) The ALDC switch should now be thrown ON, and the ALDC control should be slowly moved clockwise, reducing the back bias on the ALDC rectifier.

(4) When the PA PLATE RF meter indication just commences to decrease, the ALDC control should be backed off just beyond this point.

(5) The drive control should now be reduced to zero, and the desired intelligence fed to the system. The drive control should now be advanced <u>slowly</u> until it is noted that the PA PLATE RF indication perceptively slows or fails to increase. This point will be found by experience. Now, occasional peaks exceeding the desired PEP level will automatically be compensated for.

(6) Significant changes in intelligence level, number of channels, carrier insertion and the like will have to be compensated for by a readjustment of the drive control.

(7) ALDC may be used to insure that <u>any</u> PEP level is not exceed. This merely requires that, in step (2), the two tone <u>average</u> power level be one half the final PEP level desired.

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