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RF BANDWIDTH CONSIDERATIONS VHF BUNCH DILUTION SYSTEM

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The bunch dilution cavity will be located in the downstream half of the G-10 straight section. It will be a high-Q cavity (de-Q'd when rf is off) tuned at a fixed frequency. The rf drive for the cavity will have a power profile as shown in Figure 1. This rf power will be supplied by a modified commercial FM (88 to 108 MHz) power amplifier located in the F-18 house. The preliminary bunch dilution phase modulation function is shown in Figure 2. Preliminary system parameters are listed in Table I.

Table I
System Parameters

Frequency	91.56 MHz
Power delivered to cavity	20 KW
Cavity Q	1500
Power amplifier power output	30 KW min.
Power amplifier FM deviation	±75 kHz
Power amplifier FM bandwidth	150 kHz
Maximum phase deviation	π

The output of the power amplifier will be a resonant circuit tuned to the same frequency as the cavity. The resultant bandwidth of two cascaded synchronously-tuned equal-bandwidth circuits will be 0.64 the individual bandwidths.[1] However, if one of the synchronously tuned circuits has a significantly wider bandwidth than the other, the overall bandwidth of the pair will be determined by the narrowest bandwidth. The 3 dB bandwidth of the cavity is:

$$Q = f_o/\Delta f = f_o/BW_{3dB}$$

$$\Delta f = f_o/Q = 91.56 \text{ MHz}/1500 = 61.04 \text{ kHz}$$

The power amplifier bandwidth has been specified at 150 kHz, which is much wider than the cavity bandwidth. Thus, the high-Q cavity will be the bandwidth limiting device in the system.

The phase modulated signal, from a low level rf subsystem, will generate a series of sideband frequencies determined by the modulation index. Figure 3 illustrates the frequency spectra for a single tone frequency/phase modulated carrier frequency as a function of the modulation index. The modulation index for phase modulation, mp is defined as:

$$m_o = \frac{\Delta w}{w_m} = \phi_m = mp = \Delta\phi = \text{maximum phase deviation}$$

Where:

Δw = peak frequency deviation

w_m = modulation frequency

Figure 4 illustrates the relative amplitude of the carrier frequency (f_c) and the first twelve sideband frequency components as a function of m_o. Note that the relative amplitudes of the sidebands decrease while the number of sidebands increase as the modulation index is increased. Carson's Rule[2] states that the required bandwidth to transmit at least 98% of the sidebands of frequency or phase modulated carrier is $(1 + mp) = (1 + \Delta\phi)$.

Carson's Rule:

$$BW = 2f_m\,(mp + 1) - 2f_m\,(\Delta\phi + 1)$$

Where:

BW = bandwidth

f_m = modulating frequency

$\Delta\phi$ = peak phase deviation

$$BW = 2(6.7\text{ kHz})\,(3.14 + 1) = 55.5\text{ kHz}$$

Thus, the sidebands of the phase modulated rf drive signal will occupy 55.5 kHz/61.04 kHz = 0.91 of the 3 dB bandwidth of the cavity. From the universal resonance curve shown in Figure 5, the band edge sidebands will be down almost 3 dB from the predicted level. An additional estimated 1 dB roll-off at the band edges will be due to the power amplifier bandwidth. This band edge sideband reduction should not effect performance of the bunch dilution, since very little power would be in these sidebands, refer to Figure 4 for $m_o = 3.14$.

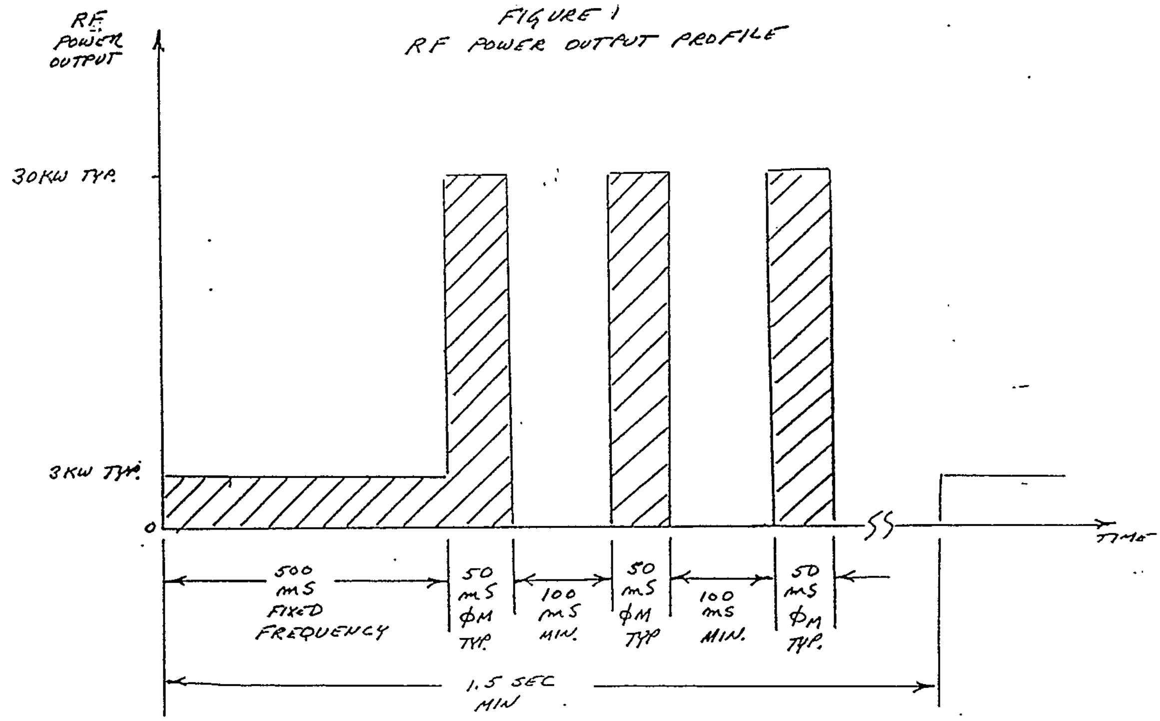
The proposed maximum modulating frequency and peak deviation, 6.7 kHz and π, have been derived from a mathematical model of the beam bunches and the dilution signal. Other combinations of modulation frequency and phase deviation will be determined emperically during machine studies for the best bunch dilution performance.

References

1. "Vacuum Tube Amplifiers", Vol. 18 Radiation Laboratory Series; Valley & Wallman, McGraw Hill, 1948, pg. 173.
2. "Solid State Radio Engineering", Krauss, Bostian, Raab, 1980, p. 242.

mvh

FIGURE 1
RF POWER OUTPUT PROFILE



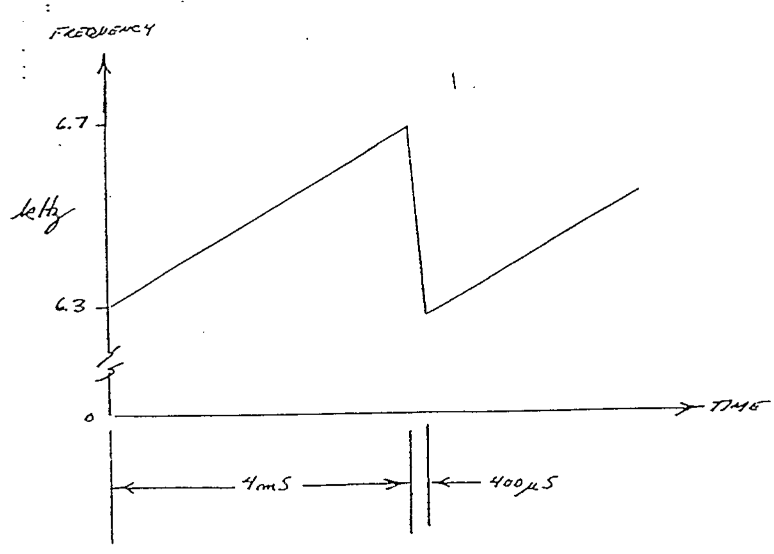


FIGURE 2
TYPICAL PHASE MODULATING FUNCTION

FIGURES 1 & 2 FROM AGS SPEC AGS-897 "30KW VHF FM POWER AMPLIFIER"

FIGURE 3

Angle modulation frequency spectra for sinusoidal modulation, with various values of m_θ. The modulation frequency is constant; $\Delta\theta$ or $\Delta\omega$ are varied to vary m_θ. (From H. J. Reich, H. L. Krauss, and J. G. Skalnik, Theory and Applications of Active Devices, Van Nostrand Reinhold Company, New York, 1966

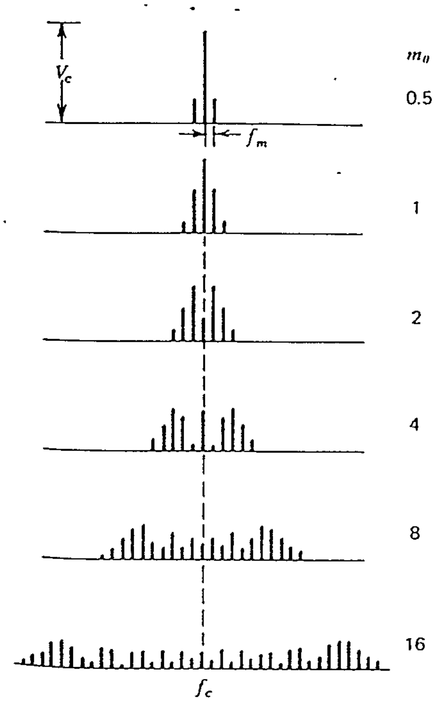
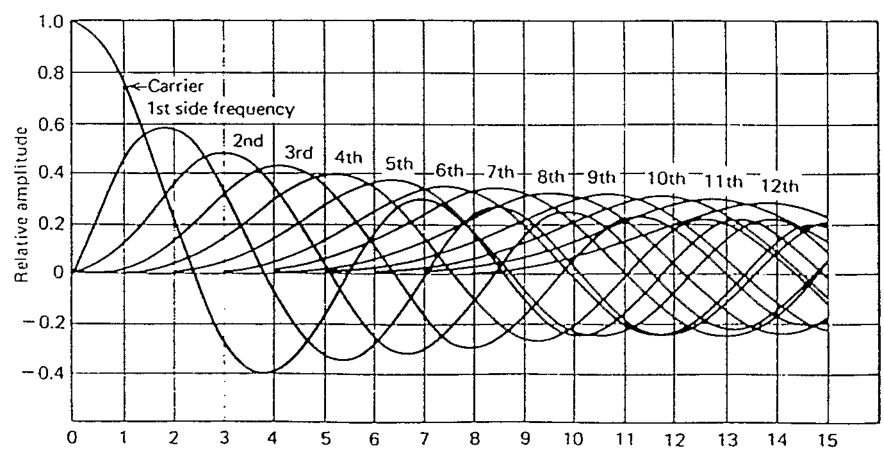


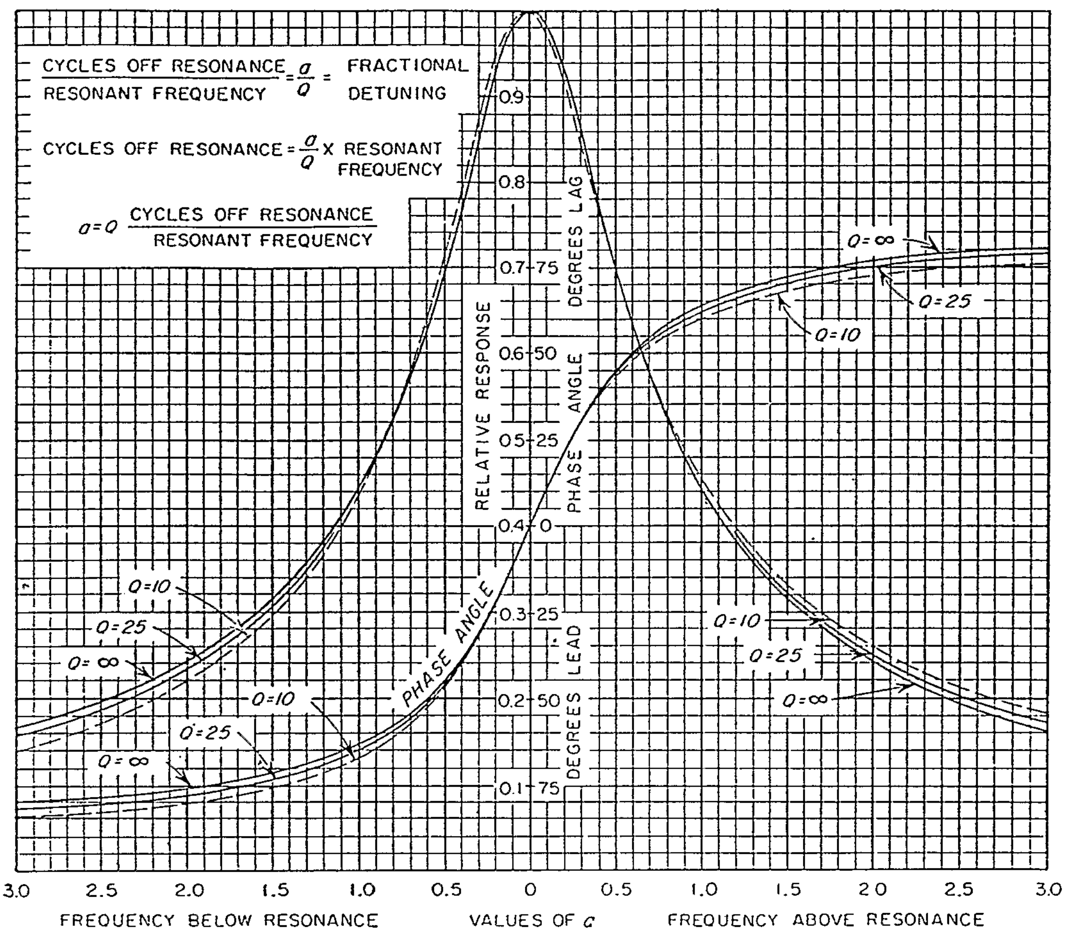
FIGURE 4

Relative amplitudes of the carrier and first 12 side-frequency components of an angle-modulated wave versus m_θ.



FIGURES 3 & 4 FROM "SOLID STATE RADIO ENGINEERING" KRAUSS, BOSTIAN, RAAB PP 240, 241

FIGURE 5



Universal resonance curve for series resonant circuit. This curve can also be applied to the parallel resonant circuit by considering the vertical scale to represent the ratio of actual parallel impedance to the parallel impedance at resonance. When applied to parallel circuits, the angles shown in the figure as leading are lagging, and vice versa.

FIGURE 5 FROM "ELECTRONIC & RADIO ENGINEERING", TERMAN P 48