3.4 FREQUENCY DOUBLING WITH PLANAR FERRITES AND ISOTROPIC FERRITES WITH LARGE SATURATION MAGNETIZATIONS

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In experiments on frequency doubling using ferrite slabs in a rectangular waveguide, planar ferrites consistently had much greater conversion efficiency than isotropic ferrites. The principle results are shown in Fig. 1. The geometry used is also shown in Fig. 1. The primary frequency was in the range of 8.5 to 9.1 kilomegacycles. The reference power level (0 db) was one watt peak power. The duty cycle was 10^{-4}. The material properties are given in the appendix.

The conversion losses at an input power level of 12,600 watts peak, are shown in Table 1.

Table 1

Material	Thickness (inches)	Conversion Loss (db)
Planar	.02	29
Planar	.04	14
Spinel	.01	39
Spinel	.04	34

The double frequency output of YIG saturated well before the input level of 12,600 watts peak, and its conversion loss was very high.

The following are believed to be the explanation of the observed data.

Resonance of Second Harmonic in Ferrite: It is believed that part of the reason for the greatly enhanced conversion efficiency in the .04 thick samples as compared to the thinner samples, is due to the fact that a cavity type resonance was possible in the .04 thick sample. This increased the radiation resistance of the sample and thus increased its conversion efficiency. In the case of the planar ferrite, efficiency was much worse with an .06 thick sample. However, the spinel had approximately the same efficiency at .06 as at .04 inches thick.

Increased Density of Primary Frequency Energy In Ferrite Due to Increased Thickness of Slabs: In the case of the planar ferrite, two pieces each .02 inches thick caused an attenuation at resonance of 9 db when placed one following the other. However, when one piece was placed on top of the other, the attenuation was 12.3 db. This shows that in the thicker geometry more of the radio frequency energy is drawn into the ferrite, thus enhancing conversion efficiency.

Asymmetry in the Transverse Plane: High conversion efficiency requires a large degree of asymmetry in the transverse plane. With the geometry used, the asymmetry is proportional to $Ha + 4\pi Ms \cdot Nz$. Ha is the magnetic anisotropy field and is present only in the planar ferrite; $4\pi Ms$ is the saturation magnetization, and Nz a demagnetizing factor. Since the anisotropy field can be much larger than the saturation magnetization, the great advantage of planar ferrites is clear.

Spin Waves: In the case of planar ferrites, the magnetic moments of both long and short spin waves precess in elliptical paths, thus contributing to the harmonic generation just as much as the uniform precession. In the case of isotropic ferrites, the magnetic moments of short spin waves precess in circular paths and do not contribute to harmonic generation. However, the magnetic moments of long spin waves precess in elliptical paths and therefore contribute to harmonic generation.

Simple theory predicts that for every one db increase in input power, the double frequency output should increase by 2 db. From Fig. 1 we note that for the .02 inch planar ferrite, the rate is 2.6 db increase in output for each one db increase in input. This is believed due to the gradual onset of spin waves. Since spin waves have very narrow line widths, the onset of spin waves can actually increase the second frequency output in the case of planar ferrites.

Figure 2 shows that the normalized attenuation (at ferromagnetic resonance) is due to the spinel and YIG samples as a function of input power. In the case of the spinel, the rapid decrease in attenuation is due to long spin waves and the harmonic generation remains efficient. In the case of YIG, the spin waves are very short, and the harmonic output has a sharp cutoff at a power level a little higher than that at which the normalized attenuation drops below unity.

Appendix: Material Properties

	4 Ms (gauss)	Ha (oersteds)	ΔH (oersteds)
Planar		12,000	260
Spinel	4,500	–	165
YIG	1,800	–	70

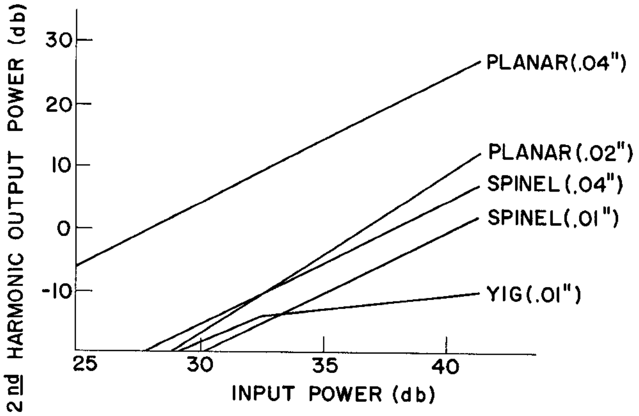

Figure 1 - Harmonic Output vs Input.

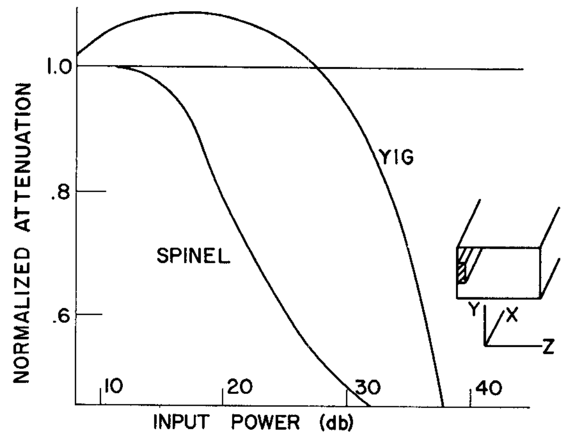

Figure 2 - Normalized Attenuation vs Power Input.