Response to AI_04-01: DOR Spectra Through Saturated Power Amplifier

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I. Introduction

Action item AI_04-01 was issued at the May 2004 meeting to produce DOR tone spectra through a saturated power amplifier. The DOR tone spectra were taken using the Mars Reconaissance Orbiter Small Deep Space Transponder (SDST). The SDST implements a phase-modulated sinewave DOR tone which can be expressed mathematically as:

$$s(t) = \sqrt{2P}\cos\left(2\pi f_c t + \theta_{DOR}\sin\left(2\pi f_{DOR} t\right) + \phi_0\right)$$

where θ_{DOR} is the peak DOR mod index in radians, f_{DOR} is the DOR tone frequency, and ϕ_o is an arbitrary phase offset. At Ka-band, two simultaneous DOR tones can be transmitted simultaneously with the MRO transponder along with a telemetry subcarrier. In this case, the signal is expressed as:

$$s(t) = \sqrt{2P}\cos\left(2\pi f_c t + \theta_m d(t) + \theta_{DOR1}\sin\left(2\pi f_{DOR1} t\right) + \theta_{DOR2}\sin\left(2\pi f_{DOR2} t\right) + \phi_0\right)$$

where θ_m is the telemetry modulation index and d(t) is the telemetry symbol sequence.

II. DOR tone spectra

The spectra were first taken at the output of the SDST before the power amplifier, and then at the output of the saturated power amplifier following the RF Load and coupler. Figure 1 shows a block diagram of the spectrum measurement test setup. The spectra at the output of the TWTA were taken during the MRO DSN compatibility test.

Figures 2 thru 5 show the 19.2 MHz DOR tone spectra before and after the Ka-band 35W TWTA operating in saturation. The DOR spectra do not show much of a difference before and after the TWTA. Note that the C_1/C_0 ratio of –12 dB corresponds to a peak DOR tone mod index of roughly 28 degrees.

The spectra look similar at the input and output of the SDST because the DOR tones are phase modulated. The RF signal is constant envelope with only a minor frequency roll-off of the exciter. With a near constant envelope signal, the output of the TWTA will have relatively little distortion on the signal even though it is operating in the saturated region.

Figures 6 and 7 show spectra with simultaneous 19.2 MHz and 76.7 MHz DOR tones at Ka-band before and after the saturated TWTA. The harmonics of the lower frequency

DOR tone are useful in resolving phase ambiguity in the DOR measurement. Again, the spectra before and after the TWTA are quite similar.

Figures 8 and 9 show 19.2 MHz DOR tone spectra before and after the saturated X-band 100W TWTA. Again the spectra appear very similar in both cases.

Figure 10 thru 14 show the spectra of simultaneous 19.2 MHz and 76.7 MHz Ka-band DOR tones with a high frequency subcarrier modulated at 30 degrees. The high frequency subcarrier (namely 4 MHz and 6 MHz) help produce additional harmonics and intermod tones which cause also be used to resolve ambiguity in the DOR measurement if needed.

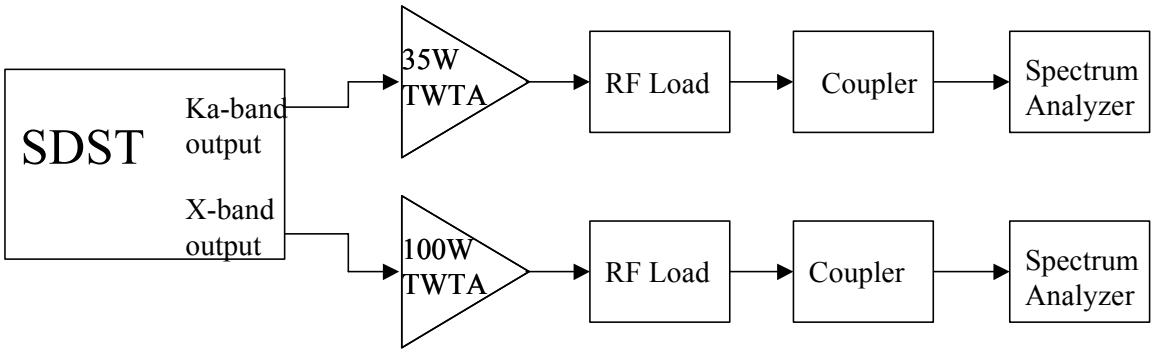

Figure 1. Test Setup

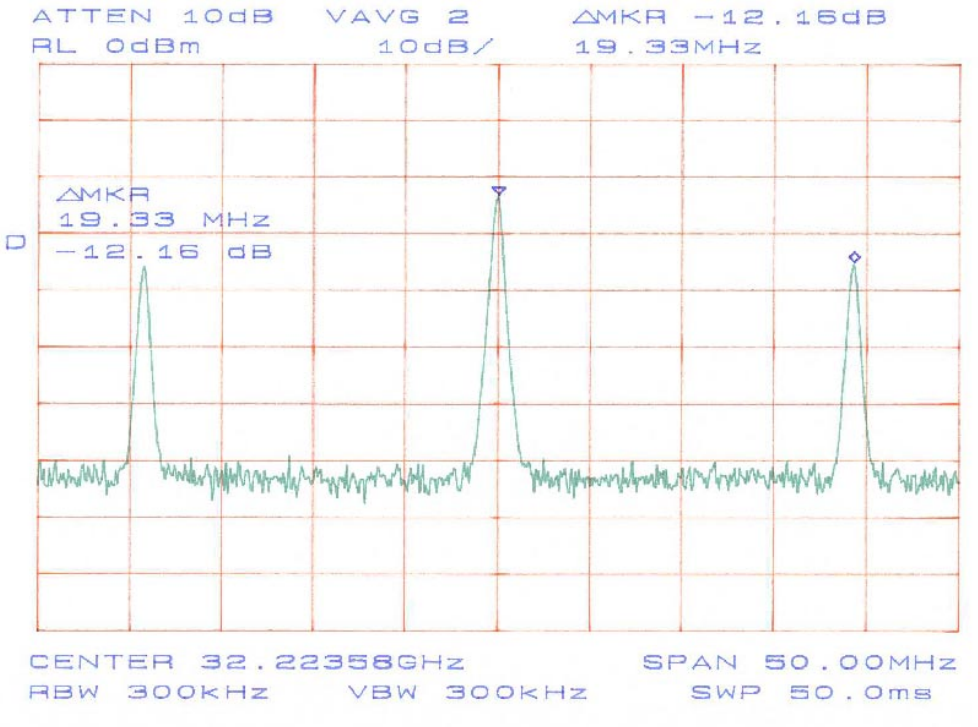

Figure 2. Ka-band 19.2 MHz DOR tones before TWTA, 50 MHz Span

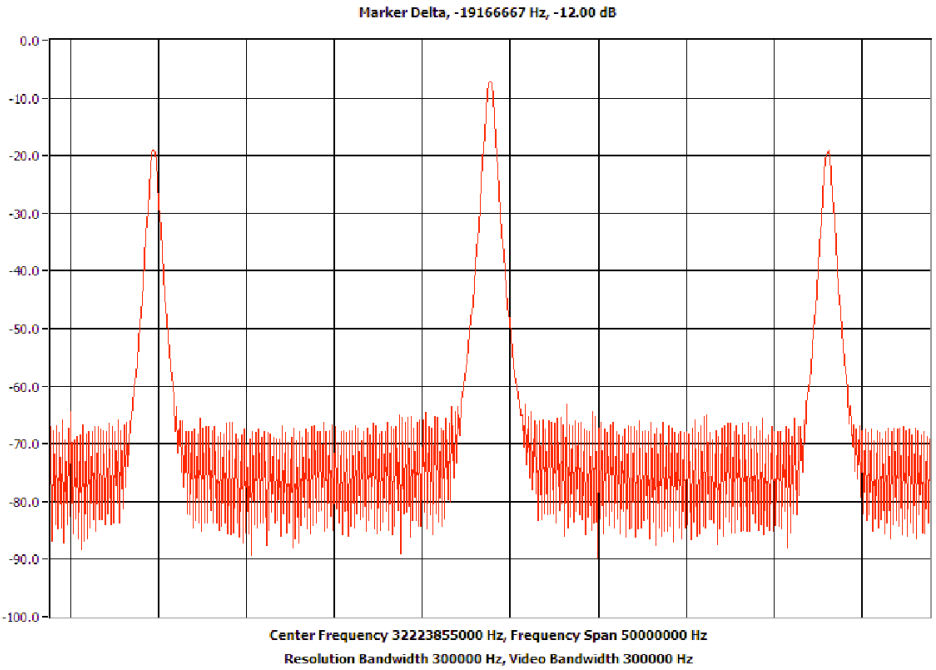

Figure 3. Ka-band 19.2 MHz DOR tones after TWTA, 50 MHz Span

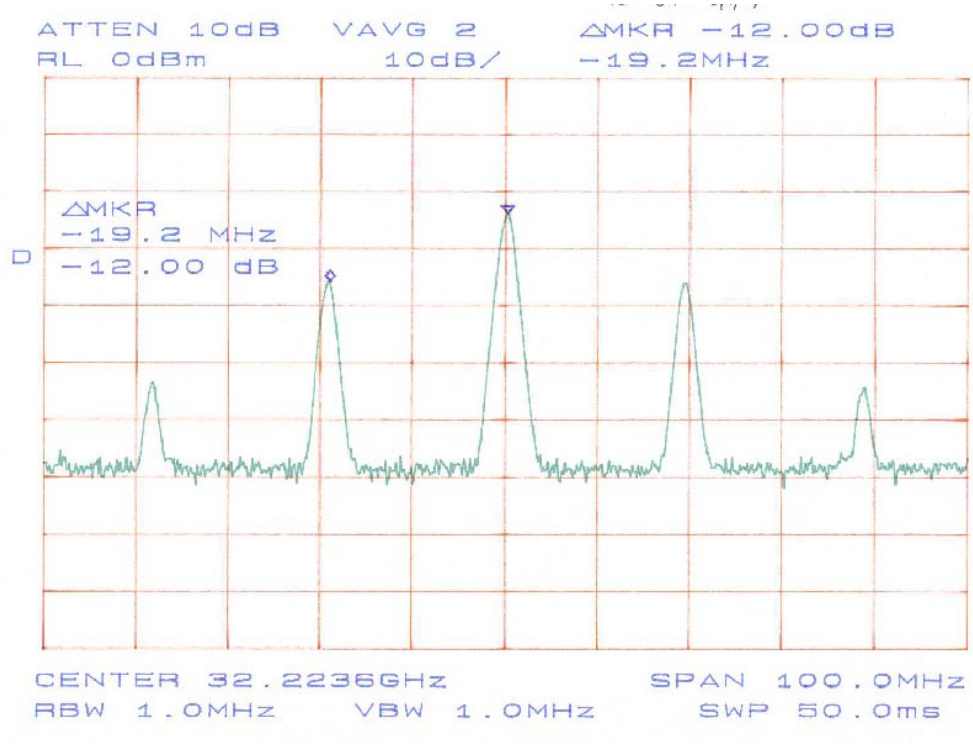

Figure 4. Ka-band 19.2 MHz DOR tones before TWTA, 100 MHz Span

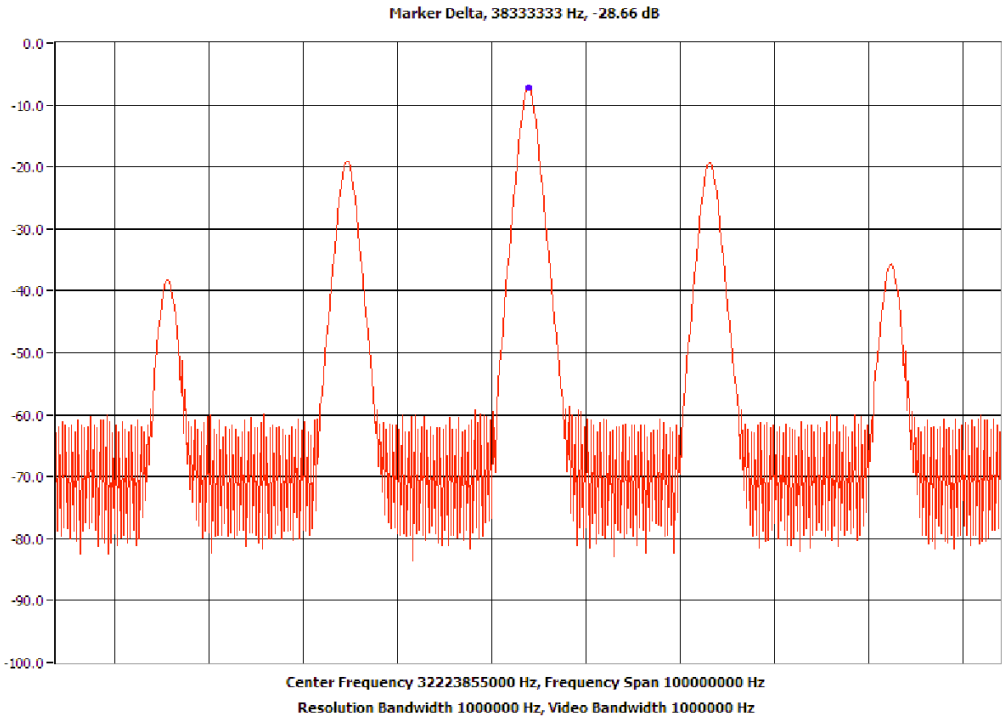

Figure 5. Ka-band 19.2 MHz DOR tones after TWTA, 100 MHz Span

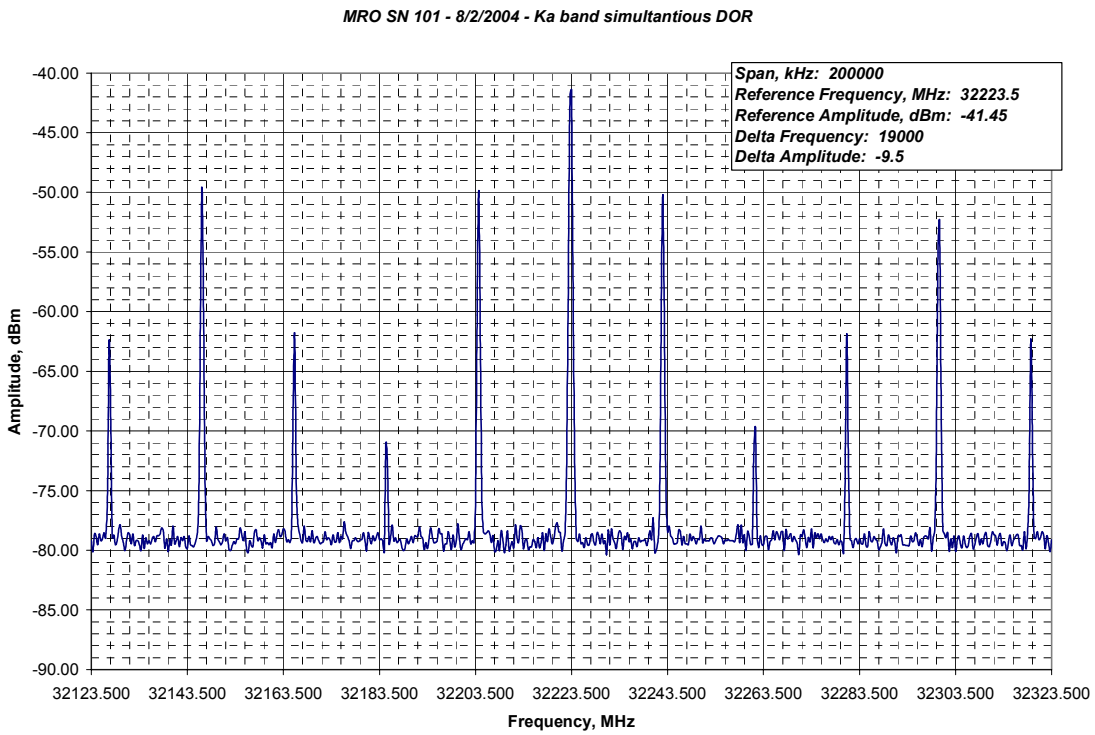

Figure 6. Simultaneous Ka-band 19.2 MHz & 76.7 MHz DOR tones before TWTA, 200 MHz Span

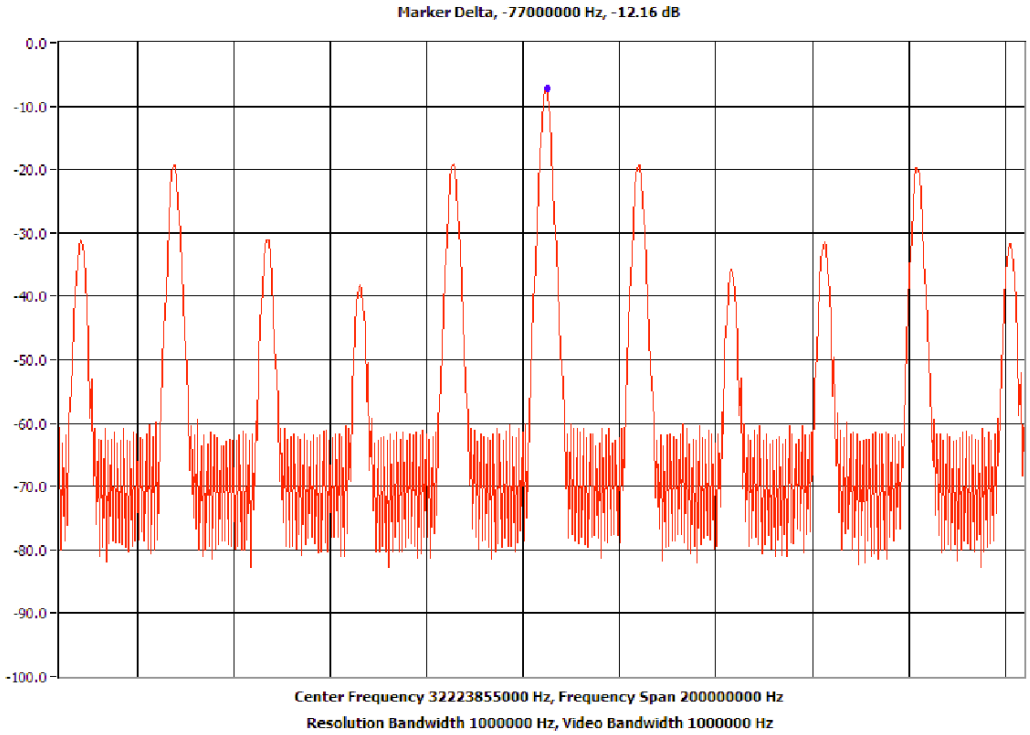

Figure 7. Simultaneous Ka-band 19.2 MHz & 76.7 MHz DOR tones after TWTA, 200 MHz Span

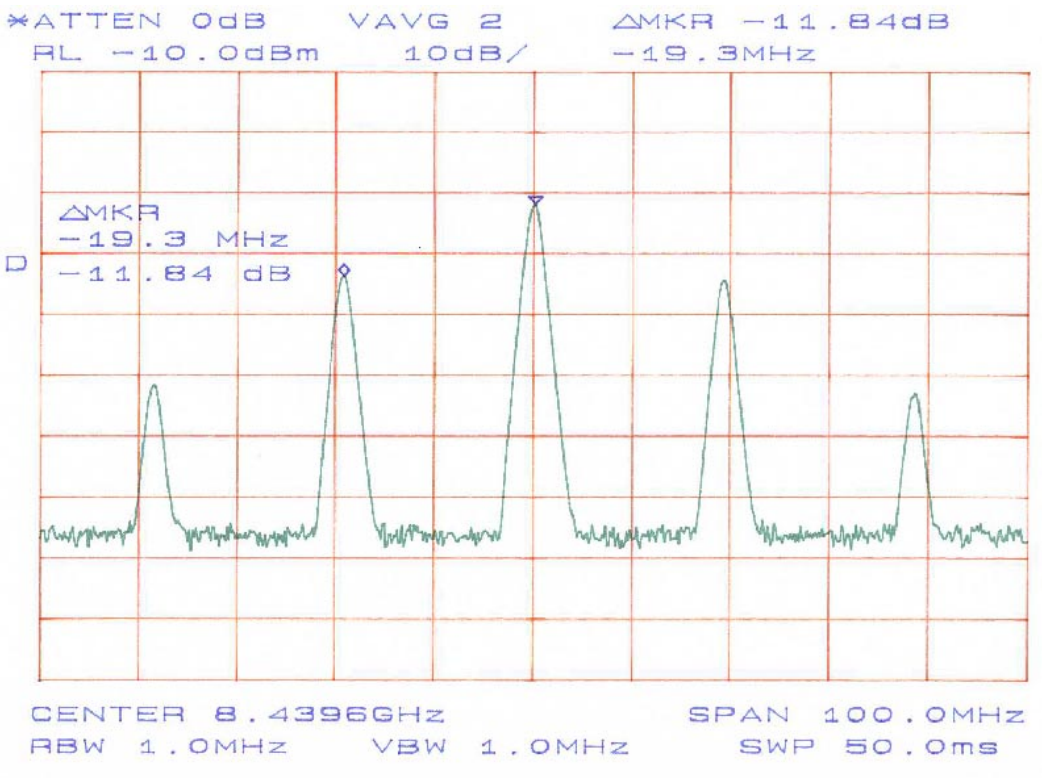

Figure 8. X-band 19.2 MHz DOR tones before TWTA, 100 MHz Span

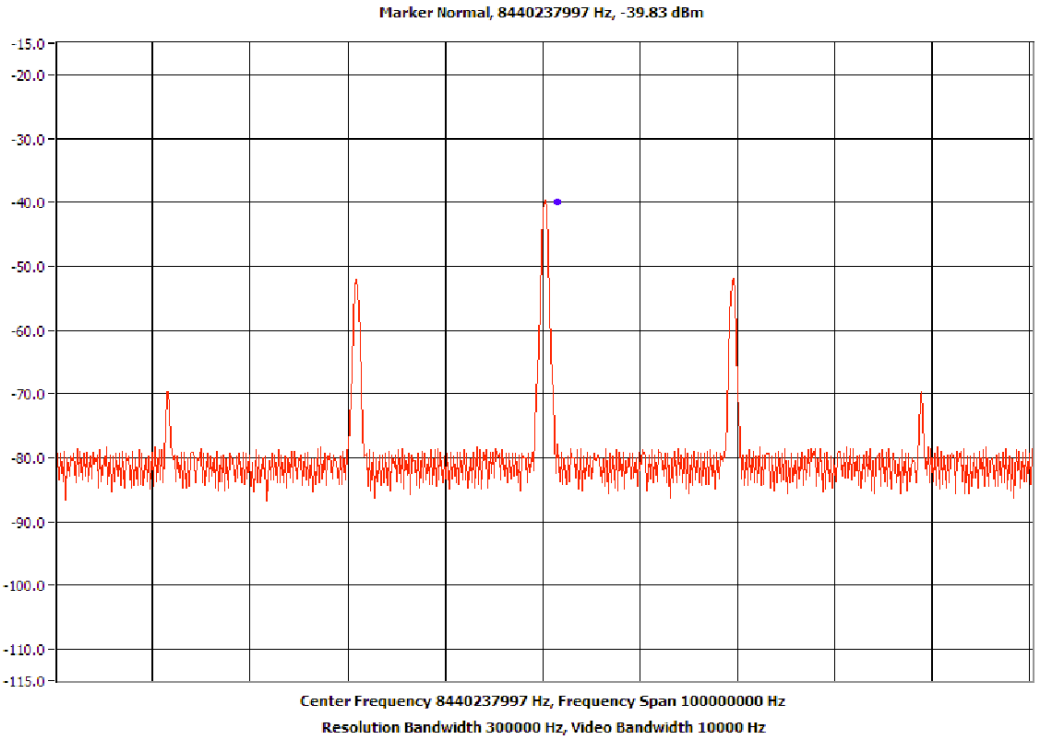

Figure 9. X-band 19.2 MHz DOR tones after TWTA, 100 MHz Span

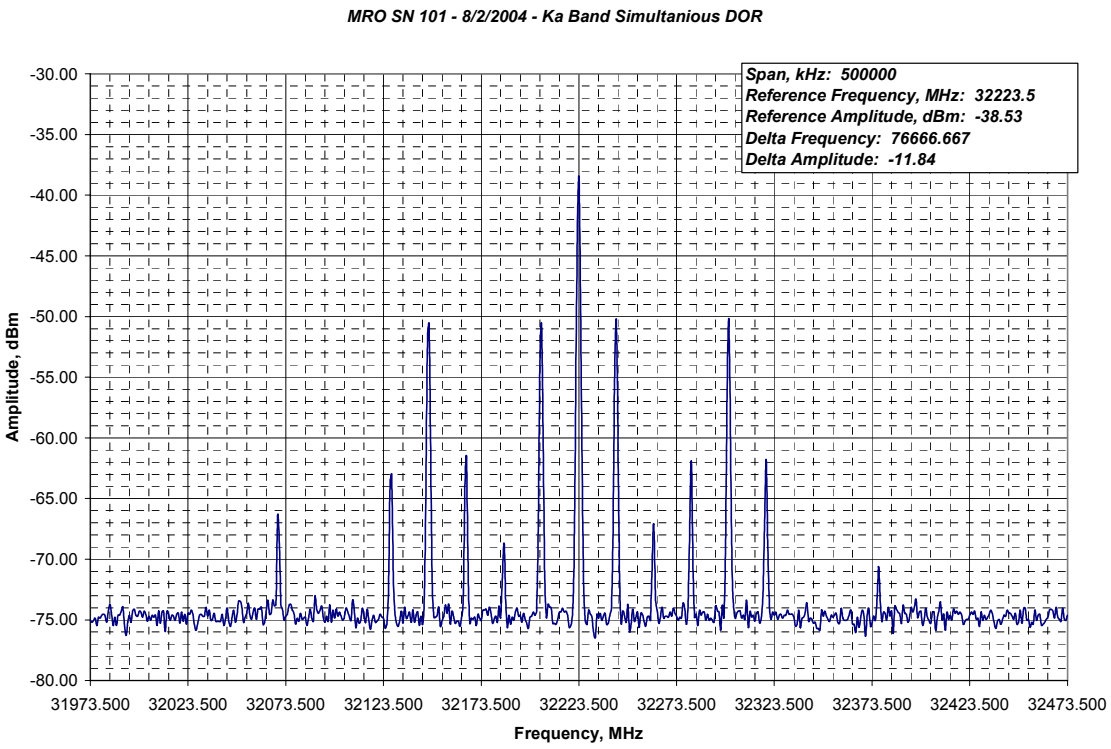

Figure 10. Ka-band 2F1 and 8F1 Simultaneous DOR Tones, Span 500 MHz

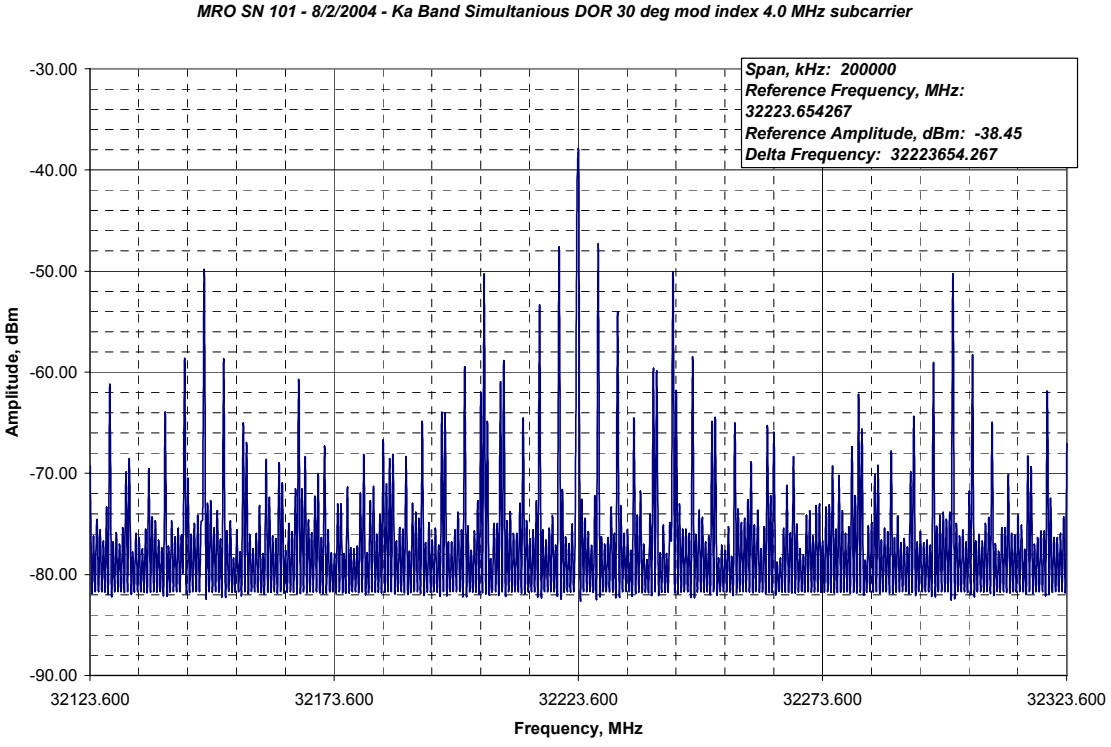

Figure 11. Ka-band Simultaneous 2F1 and 8F1 DOR tones with 4 MHz Subcarrier (30 deg mod index); 200 MHz span

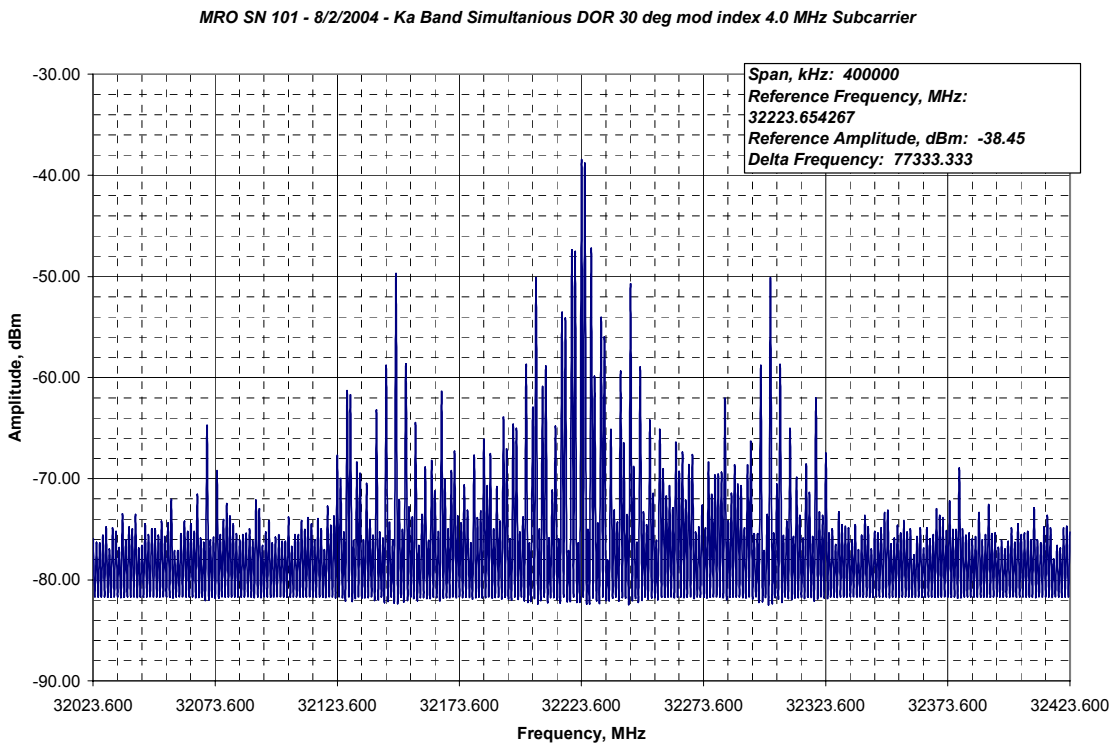

Figure 12. Ka-band Simultaneous 2F1 and 8F1 DOR tones with 4 MHz Subcarrier (30 deg mod index); 400 MHz span

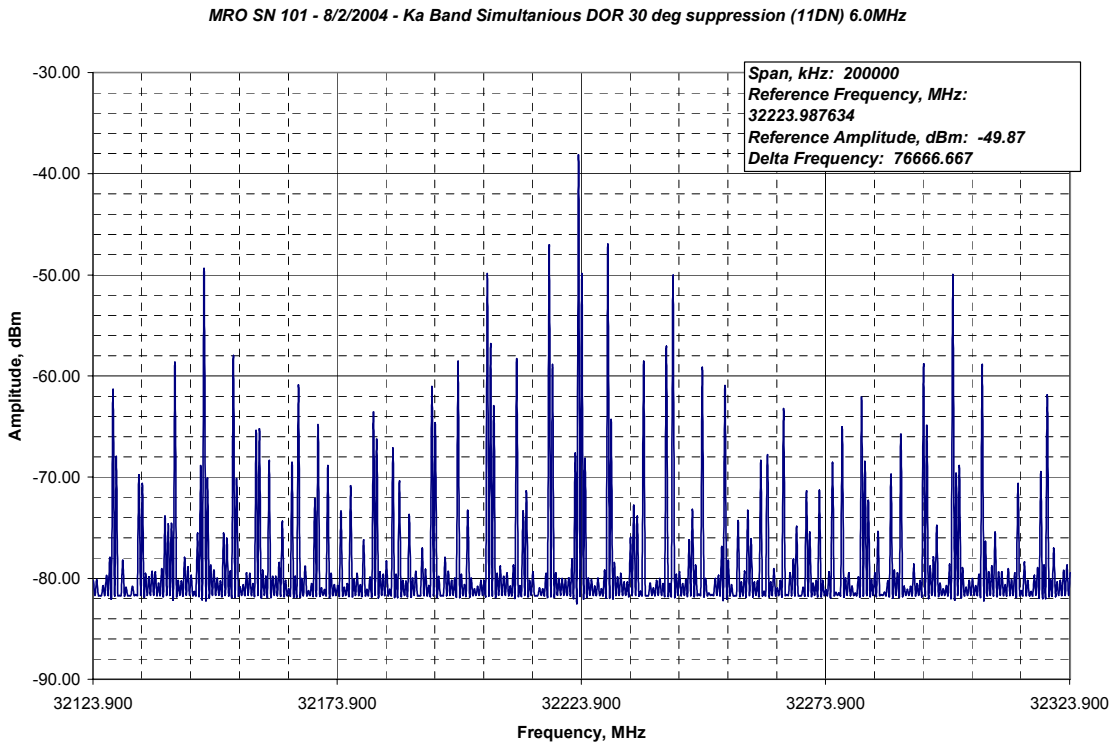

Figure 13. Ka-band Simultaneous 2F1 and 8F1 DOR tones with 6 MHz Subcarrier (30 deg mod index); 200 MHz span

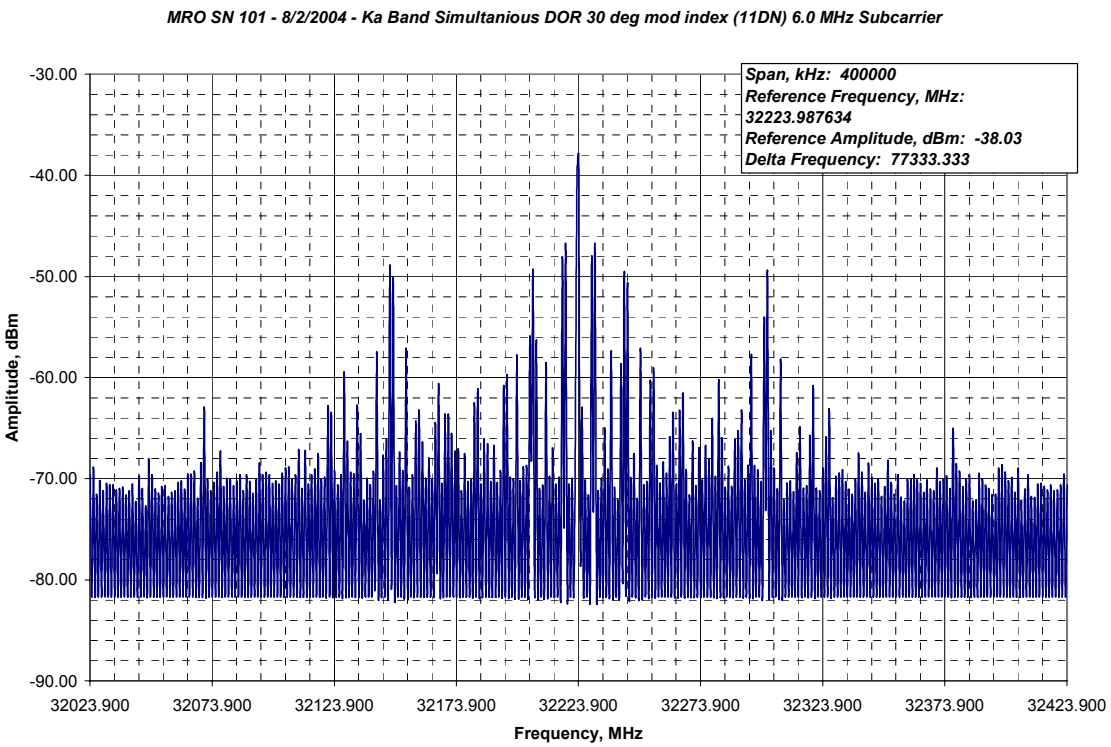

Figure 14. Ka-band Simultaneous 2F1 and 8F1 DOR tones with 6 MHz Subcarrier (30 deg mod index); 400 MHz span