ARDB Technical Note

Observation of mm-Wave Signals from an X-Band Klystron

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In this note we describe the work of three hours on the afternoon of 9/17/97 spent looking at mm-wave emissions from an X-Band Klystron. We established that mm-wave signals are detectable from an X-Band tube, without too very elaborate measures. Maximum power detected after a 50 dB (X-Band) coupler and other miscellaney is on the order of mW, except during breakdown events, where the power climbs by orders of magnitude. This intriguing connection between harmonic power and breakdown events may, however, have a prosaic explanation.

Equipment and Setup

The setup is depicted schematically in Fig. 1, and illustrated with the photographs of Figs. 2 (a) and (b). The setup was situated on top of the ASTA beam housing, adjacent to Test-Stand No. 8, home of the X-Band Klystron XL-2. Some estimates relating to this work can be found in a previous technical note.[1]

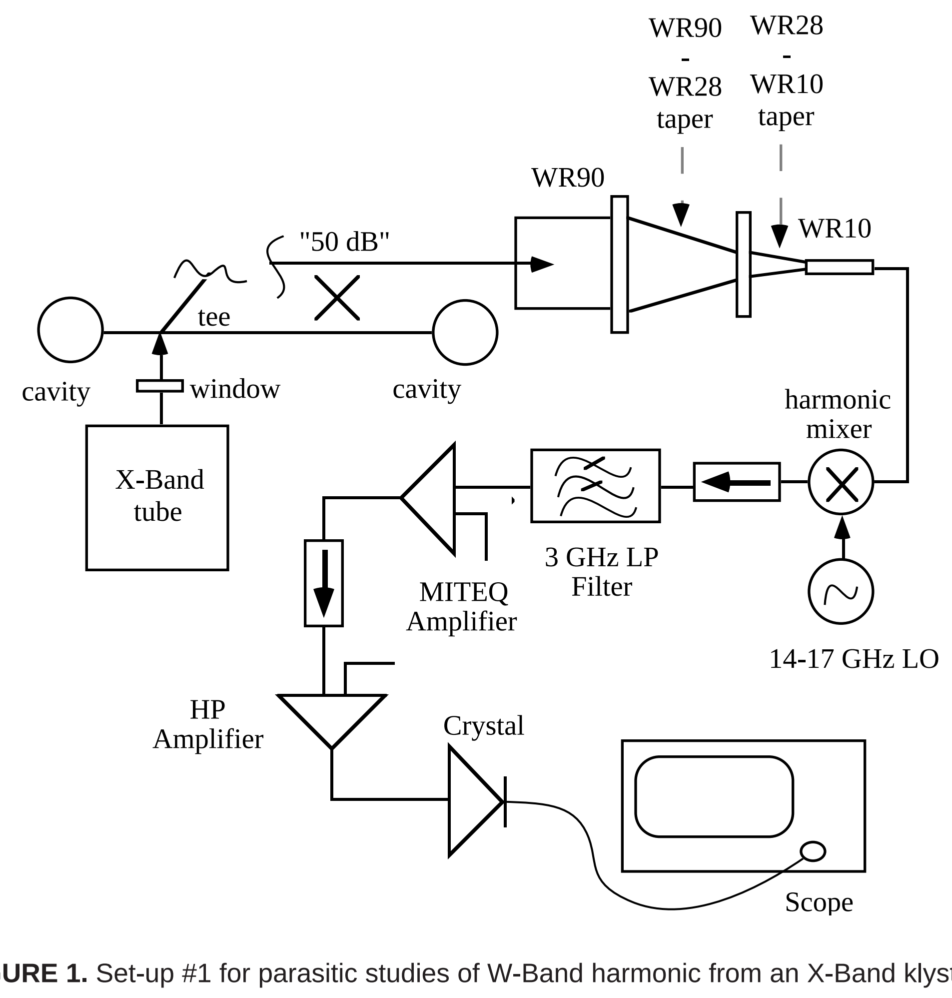

FIGURE 1. Set-up #1 for parasitic studies of W-Band harmonic from an X-Band klystron.

[1] D. H. Whittum, "W-Band Power from an X-Band Klystron", ARDB Technical Note 117

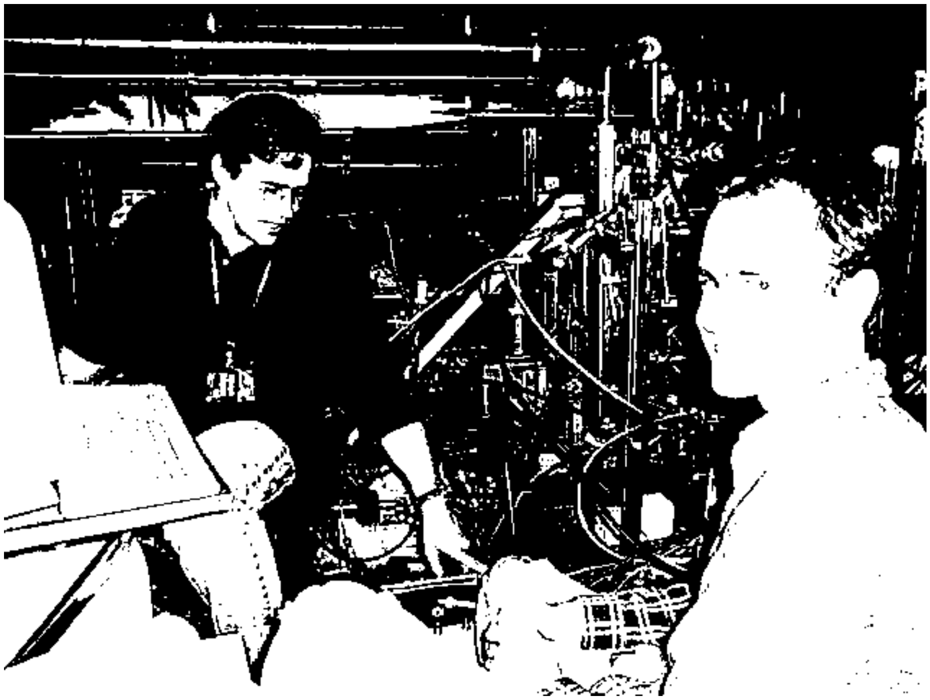

FIGURE 2(a). A view of the set-up on top of the ASTA bunker.

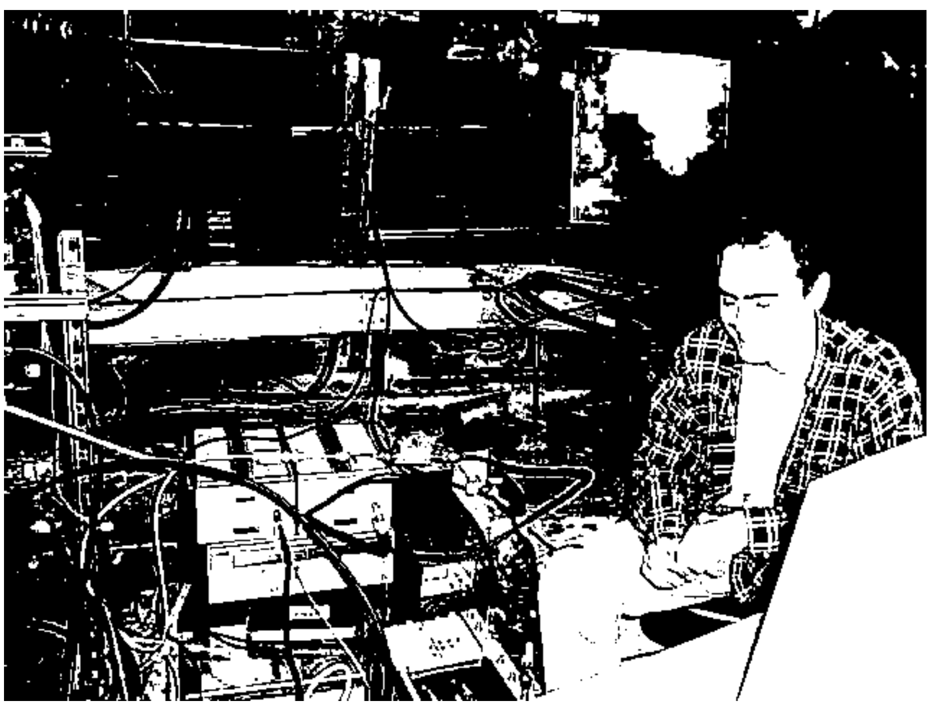

FIGURE 2(b). A better view of the set-up on top of the ASTA bunker.

The waveguide output from the klystron was run through a window and into a magic tee, on the arms of which were the two cavities being employed by David Pritzkau for his pulsed heating studies. To the forward output from one 50 dB coupler (employed for monitoring of the forward rf) we attached a WR90-WR28 taper, and to that a WR28-WR10 taper. (We should add that the qualifiers "forward" and "50 dB" apply to X-Band signals; no calibration of the network was performed for W-Band, a significant amount of work, not performed.) On the output of the final taper we mounted two inches of WR10 waveguide, with nominal cutoff frequency of 59.0 GHz. On the output of the WR10 we mounted a harmonic mixer, Model # MHP-10-RD3W from Millitech. Nominal specifications for the mixer are: LO tunable over 15-16.8 GHz, 5X multiplication and 26 dB of conversion loss, instantaneous IF band is 2-6 GHz. The mixer was not calibrated.

We employed an HP synthesizing signal generator as our LO, trusting the digital tuning and readout. The IF output we passed through an isolator, and filtered through a 3 GHz low-pass filter, putting the IF in the 2-3 GHz range, a wide bandwidth of 1 GHz. This we amplified with a low-noise MITEQ amplifier, nominal gain 20 dB, at 15 V, powered from an unregulated supply, checked with multimeter. The output from the MITEQ was then sent to an HP desktop amplifier with nominal gain of 15 dB. The output was monitored with a crystal detector observed on a scope. The crystal detector was calibrated for BLM work.

We began by taking a couple of saturation curves for XL-2, limited in maximum output power by breakdown in the pulsed heating cavities. Curves are shown in Figs. 3 (a) and (b).

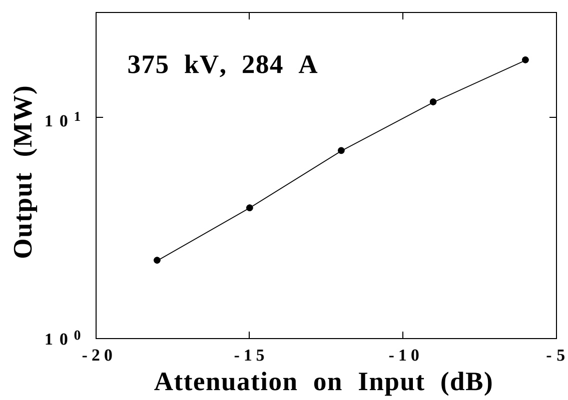

FIGURE 3 (a). First attempt at a saturation curve was taken at a beam voltage of 375 kV; breakdown was reached at the high-end. Clearly the tube wasn't saturating.

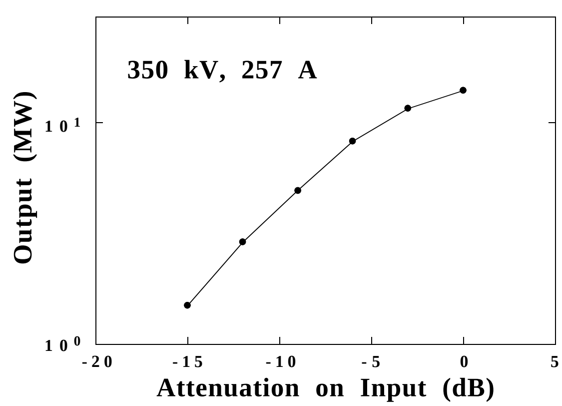

FIGURE 3(b). Second attempt at saturation curve, at 350 kV; breakdown was reached at the high-end. In this case the tube is starting to saturate. It was difficult to get closer to saturation than this, due to breakdown.

During the course of the afternoon, and looking at the mm-wave output, we examined a range of klystron beam voltages from 350 kV (257 A) to 375 kV (284 A) to

400 kV. We also sampled a range of rf drive values using an adjustable attenuator on the input line. In addition, we scanned the klystron drive frequency. Highest X-Band power employed was 20 MW (X-Band power figures quoted here are based on the calibrations used for the pulsed heating work). After adjusting the beam voltage, we would typically lower the attenuation on the input line until we were sitting at the edge of the breakdown threshold. At that point we would scan the LO frequency, looking for a signal on the crystal detector output. Typical waveforms, away from the breakdown threshold, are show in Figs. 4 (a) and (b).

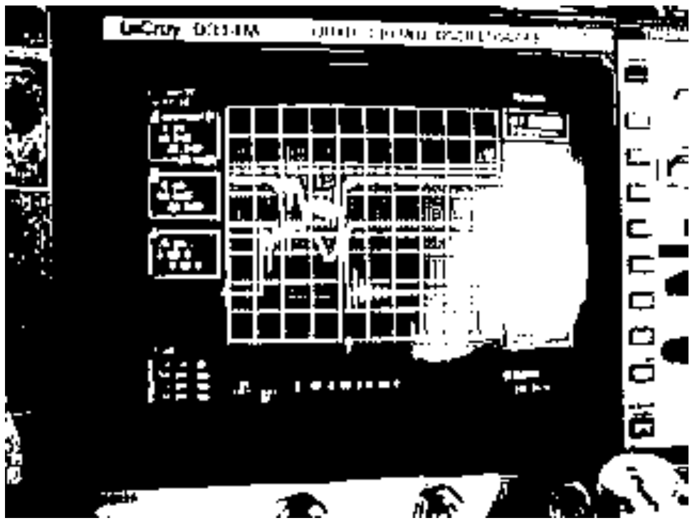

FIGURE 4(a) Typical waveform, at a point in LO drive away from the breakdown threshold. The fiducial waveform is the crystal detected output from a forward coupler, corresponding to the envelope of the forward-going X-Band output from the klystron.

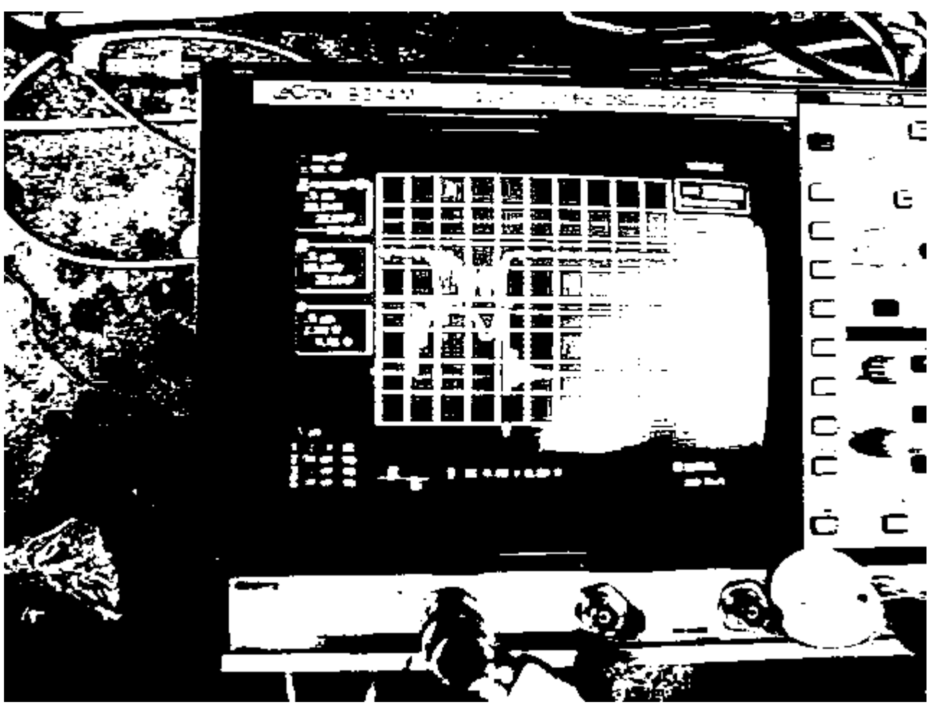

FIGURE 4 (b). As in (a) illustrating the typical waveform.

We juggled the following concerns: avoid breakdown, keep the klystron near saturation, tune the klystron drive to look for a higher-mode resonance in the output cavity, scan the mixer LO frequency to find the mm-wave signal if any. We found a couple of apparent resonances, where 10-20 mV signals could be seen on the scope, corresponding to mW level detected signals. On pulses where breakdown occured we observed that these signals went off scale. We eventually realized that the mm-wave signal correlated well with breakdown. Fig. 5 illustrates a waveform, with a large V/div setting on the scope, set to trigger at a high mm-wave signal. These triggers reliably coincided with a breakdown (that would immediately trip off the tube). Toward the end of our work, running for a few minutes with all settings fixed we observed the mm-wave signal drop over time. At this point, we made the "confident prediction" that raising the rf drive would not initiate breakdown (where it would have at the outset of that sequence). The rf drive was raised and breakdown did not occur.

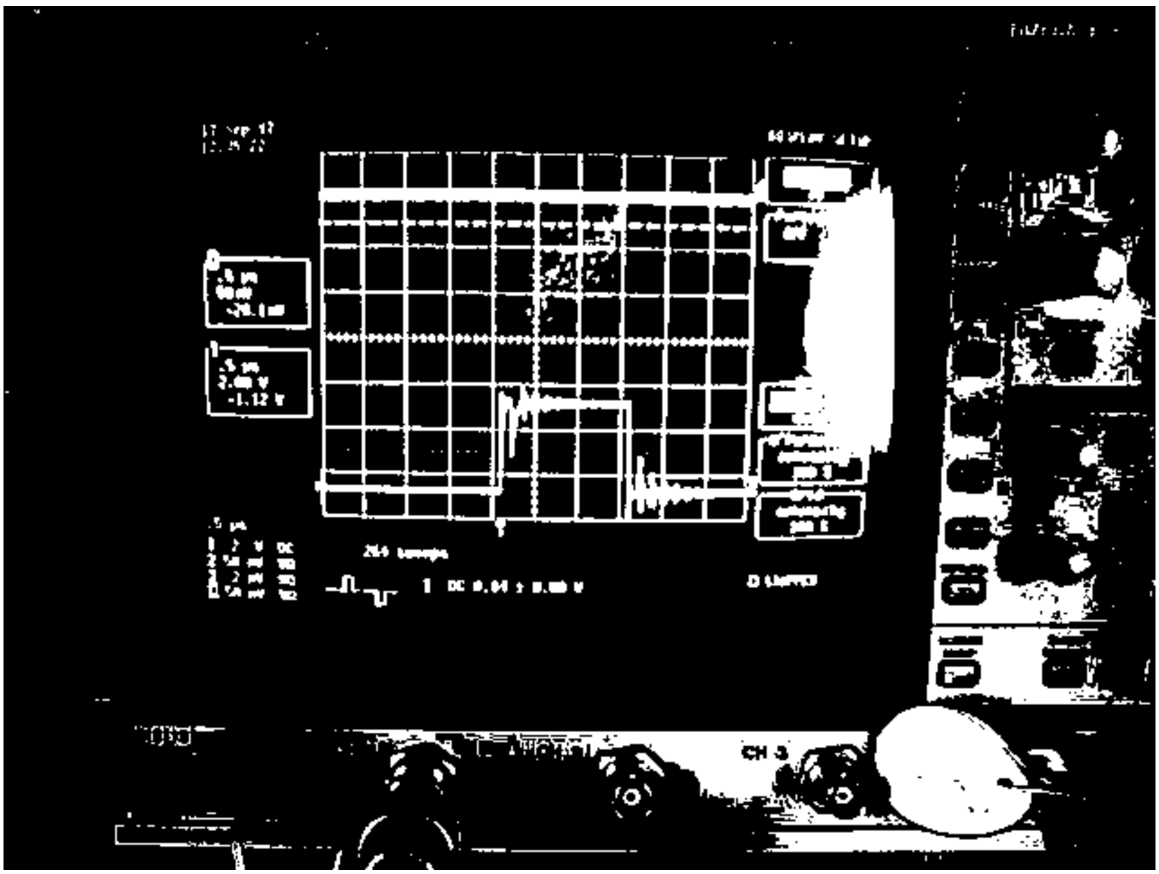

FIGURE 5. Waveform during a breakdown event, with a larger V/div setting on the scope. Forward RF amplitude looks fine.

Summary

W-Band signals are detectable from the X-Band Klystron. The 50 dB coupler commonly employed at X-Band remains to be calibrated for mm-waves. Since the setup illustrated in Fig.1 employs a network characterized well only at X-Band, a systematic issue will always remain, in such setups, of the accurate characterization of mm-wave power from the tube output.

This work, as with certain observations made during David Pritzkau's study, indicate a clear correlation between high-frequency output and breakdown events. Note too, that our attempts to saturate the klystron were frustrated by breakdown---saturated operation should be favorable to harmonic content. Let us also note that an ongoing mystery in the subject of breakdown is: why do tubes breakdown at lower field levels than accelerating structures? If harmonics are the cause of some subset of breakdown phenomena, this observation would be easily understood, as the klystron output structure is subject to more harmonic content, than an accelerator structure.

The more prosaic explanation for this association, noted by Siemann, is that breakdown may correspond to a spark, and sparks are broad-band emitters. There are practical means to study this association and clarify whether harmonic content is the cause of breakdown at these power levels, or a symptom of it. The first requirement is to instrument the device under test for detection of higher frequencies. The instrumentation must be able to acquire data on a single-shot; so, while a spectrum analyzer is useful for checks, and monitoring during normal running, for best results one should employ a set of filters, narrow and broadband, and perform power detection in each channel. Broadband emissions would show a rise on all channels, narrow-band emissions, not.