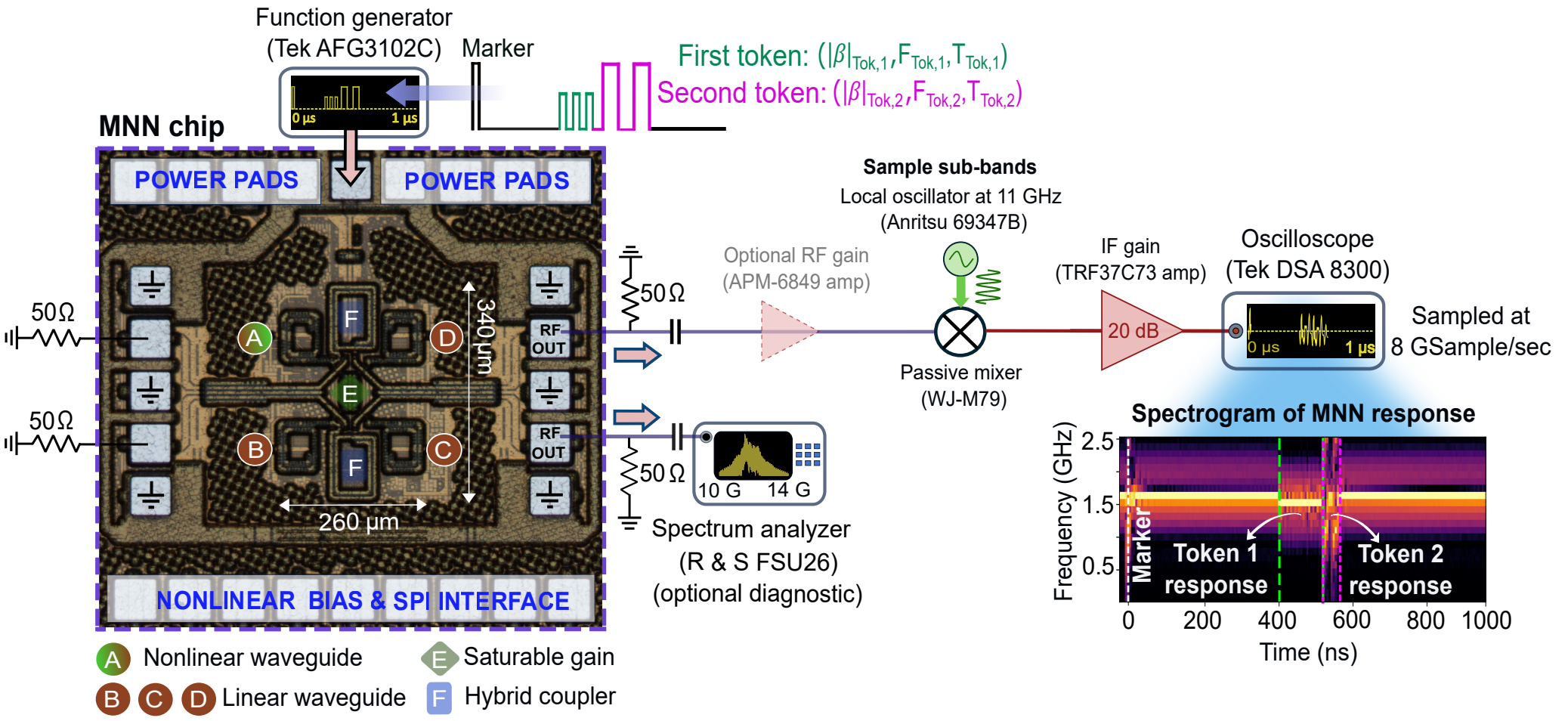
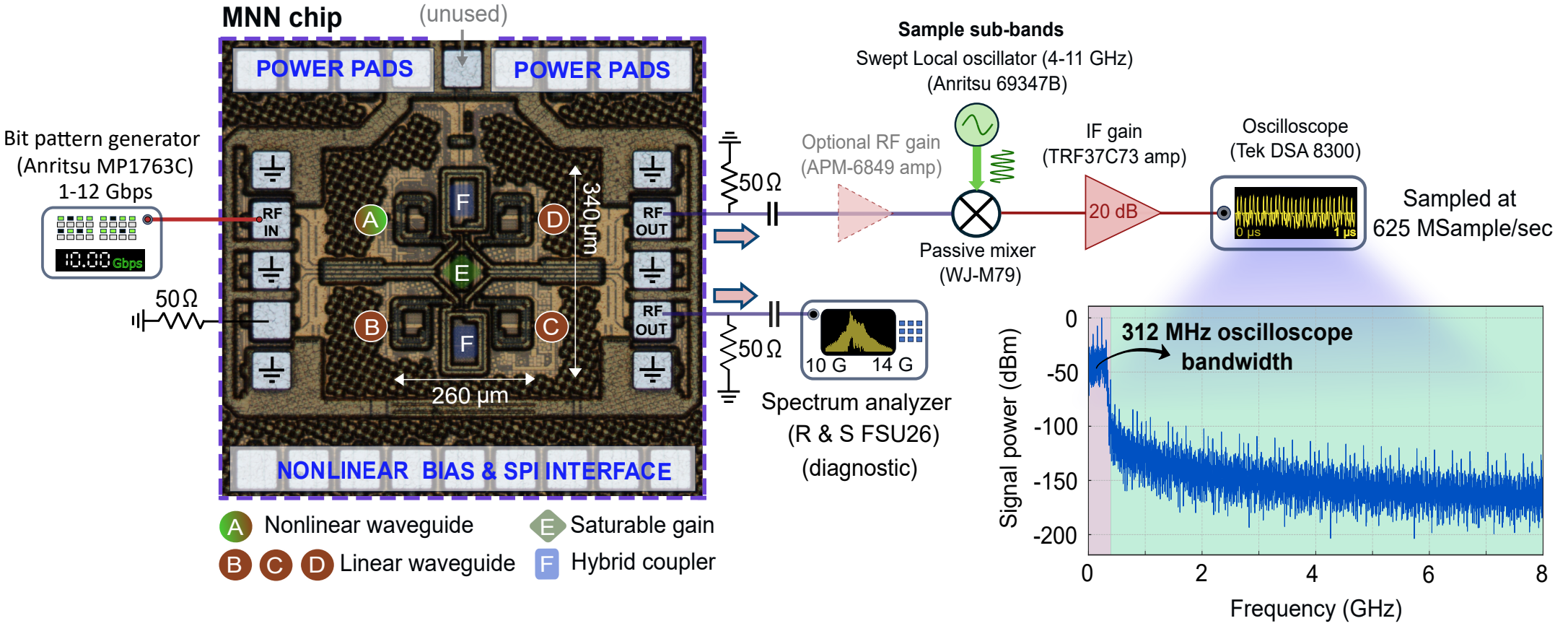
a. Experiment to inject RF pulse tokens into the MNN,and record its responses to infer token relationships from spectrograms



b. **Experimental setup to record MNN's responses to fast data to assess p-bit behavior.**



Extended Data Figure 2. Experimental setups for MNN-based feature extraction and analog spectral compression. a, Two encoded RF pulse-train tokens are sequentially injected into the MNN. The chip's nonlinear resonances redistribute spectral energy across a wide instantaneous bandwidth. After downconversion with an 11 GHz LO and baseband amplification (20 dB), the MNN response is sampled at 8 GSa/s. The resulting spectrogram exhibits distinct broadband signatures associated with each token, enabling token-to-token relationship extraction. **b,** Test of redistribution of input spectral components across the MNN output and to generation of probabilistic bits from multiple (~300) repetitions of each 8-bit input word (256 total patterns), for all LO frequencies swept in 400 MHz steps from 4 GHz to 11 GHz. High-speed digital patterns at 2.5 Gbps are applied directly to the MNN through one waveguide while the parametric token-control port remains inactive. Only a narrow ~312 MHz baseband bandwidth is sampled to emulate an 8× reduction in the effective sampling rate. For visualization only, the baseband waveform is upsampled to assess the oscilloscope's inbuilt anti-alias filtering when operated at 625 MSa/s.