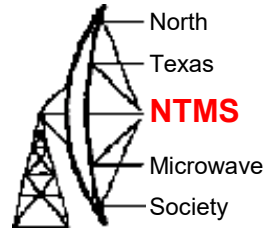


New and old technologies come together

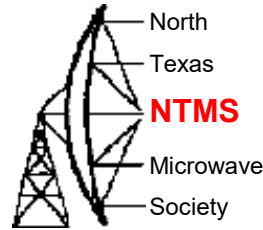
KM5PO – Jim McMasters
October 10, 2026

Antenna Range



- Inspired by-
- Conversations with Kent Britain, WA5VJB.
- Central States presentation by Kent O'Dell, KA2KQM.
- The need for another NTMS antenna range for VHF/UHF/10/24 GHz and higher.
- Acquisition of multiple HP415E from Bob Stricklin.
- Crystal detector and load resistor loaned by Mats and later acquired myself.

Design



- For the source 10 GHz signal, modulate a Gunnplexer with Arduino “bias chopper” at 1 KHz to match HP415E audio requirement.
- This will leverage the higher stability of a crystal/resonator on the Arduino board. Other alternatives were considered.
- Nano/Uno pin 9 drives common MOSFET directly (IRLZ44N)
- Build two separate power supplies with a 12v input and 5v output (Arduino) and 9-10v output @ 350-400 mA (Gunnplexer).

The Gunnplexer¹

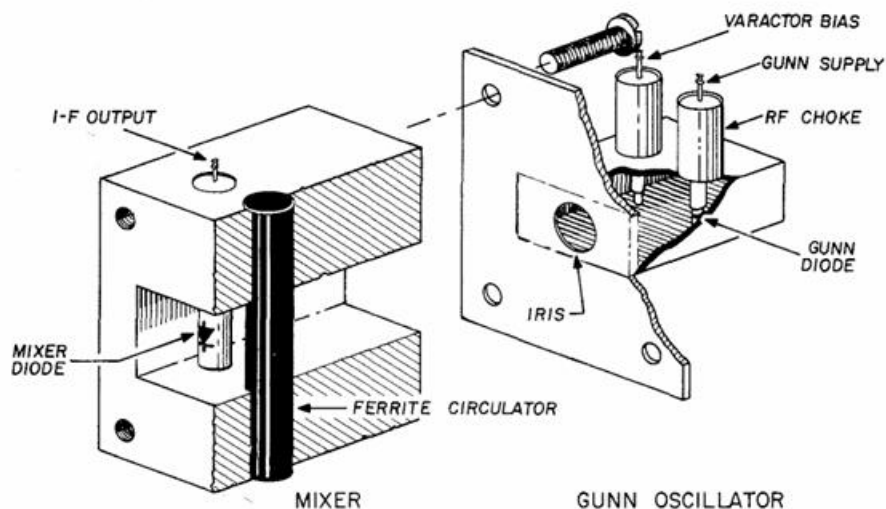
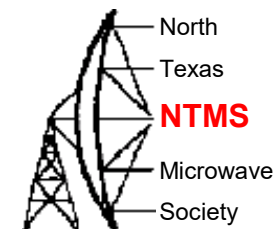


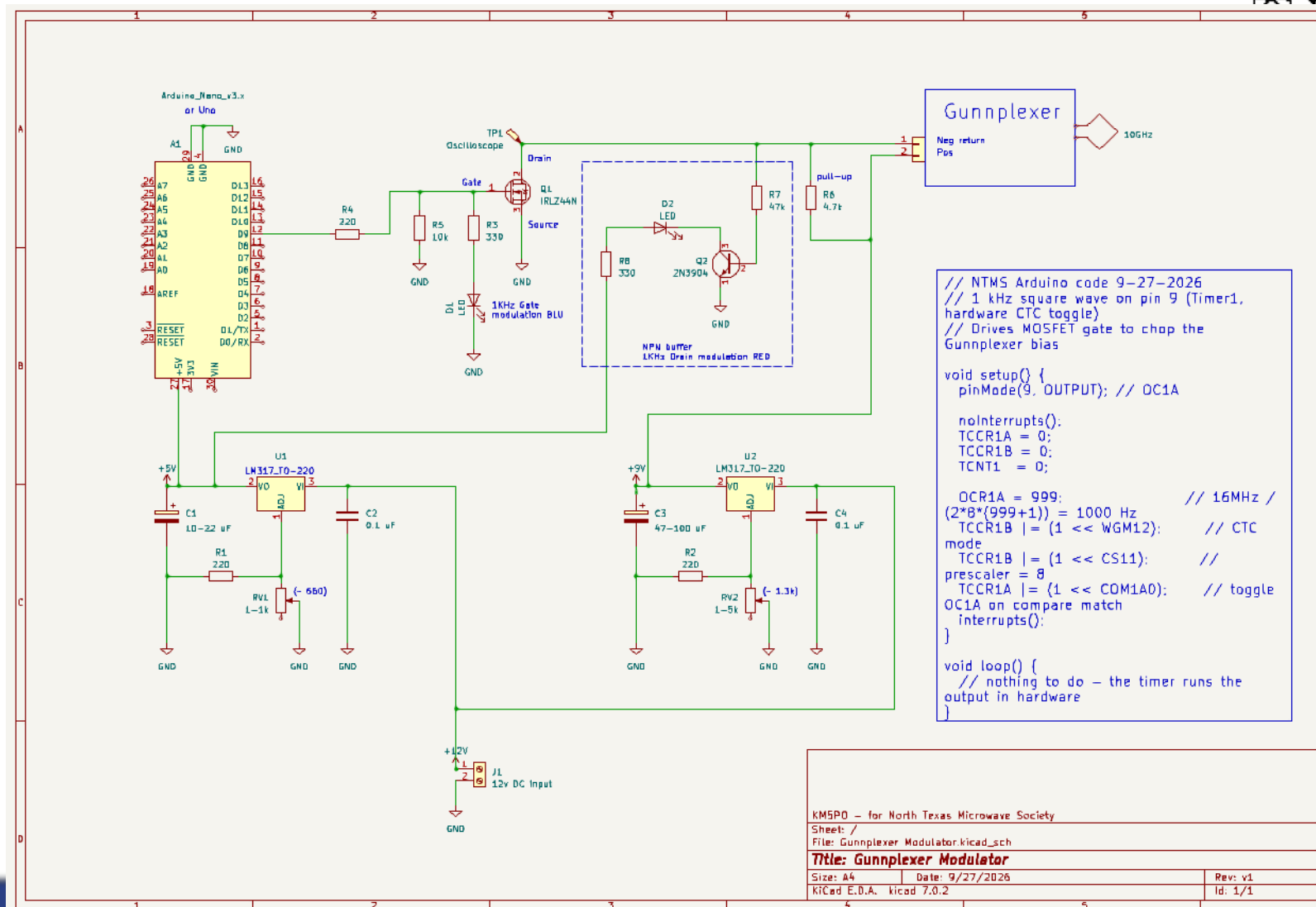
Figure 1-5.

Exploded drawing of the Gunnplexer cavity, ferrite circulator, and mixer diode (drawing courtesy *ham radio magazine*).

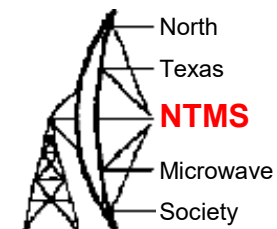
Table 1. Operating Specifications of the Microwave Associates 10-GHz Gunnplexer.

Rf center frequency	optional (10.250 GHz desired)
Rf power output	15-40 mW
Tuning: mechanical	± 100 MHz minimum
electronic	60 MHz minimum
Temperature stability	-350 kHz per degree C
Power output variation	less than 6 dB with temperature
Frequency pushing	15 MHz per volt maximum
Noise figure	12 dB maximum
Power requirements	
Gunn supply voltage	+10 Vdc
Gunn current	500 mA maximum
Varactor voltage	+1 to +20 Vdc
Rf connector	mates with UG-39/U flange
Operating temperature	-30 to +70 degrees C

Modulator schematic

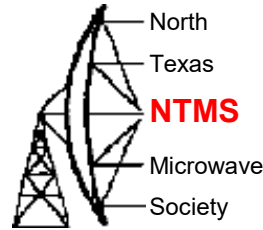


BOM



Component Count:	21			
Ref	Qty	Value	Cmp name	Footprint
A1	1	Arduino	Arduino Nano/Uno	
C1, C3	2	10-22 uF	UCB1C100MCL1GS	
C2, C4	2	0.1 uF	Chip	
D1	1	LED	LED	
J1	1	12v DC input	Screw_Terminal_01x02	
J2	1	Gunnplexer connections	Conn_01x02	
Q1	1	IRLZ44N	IRLZ44N	TO-220
R1, R2, R4	3	220R		
R3	1	1K	R	
R5	1	10k	R	
R6	1	4.7k	R	
RV1	1	1k	R_Potentiometer_1	
RV2	1	5k	R_Potentiometer_1	
TP1	1	Oscilloscope	TestPoint_Probe	
U1, U2	2	LM317_TO-220	LM317_TO-220	TO-220

Program for Arduino



```
// 1 kHz square wave on pin 9 (Timer1, hardware CTC toggle)
// Drives mosfet gate to chop the Gunnplexer bias for AM

void setup() {
  pinMode(9, OUTPUT); // OC1A

  noInterrupts(); do not disturb
  TCCR1A = 0;
  TCCR1B = 0;
  TCNT1 = 0;

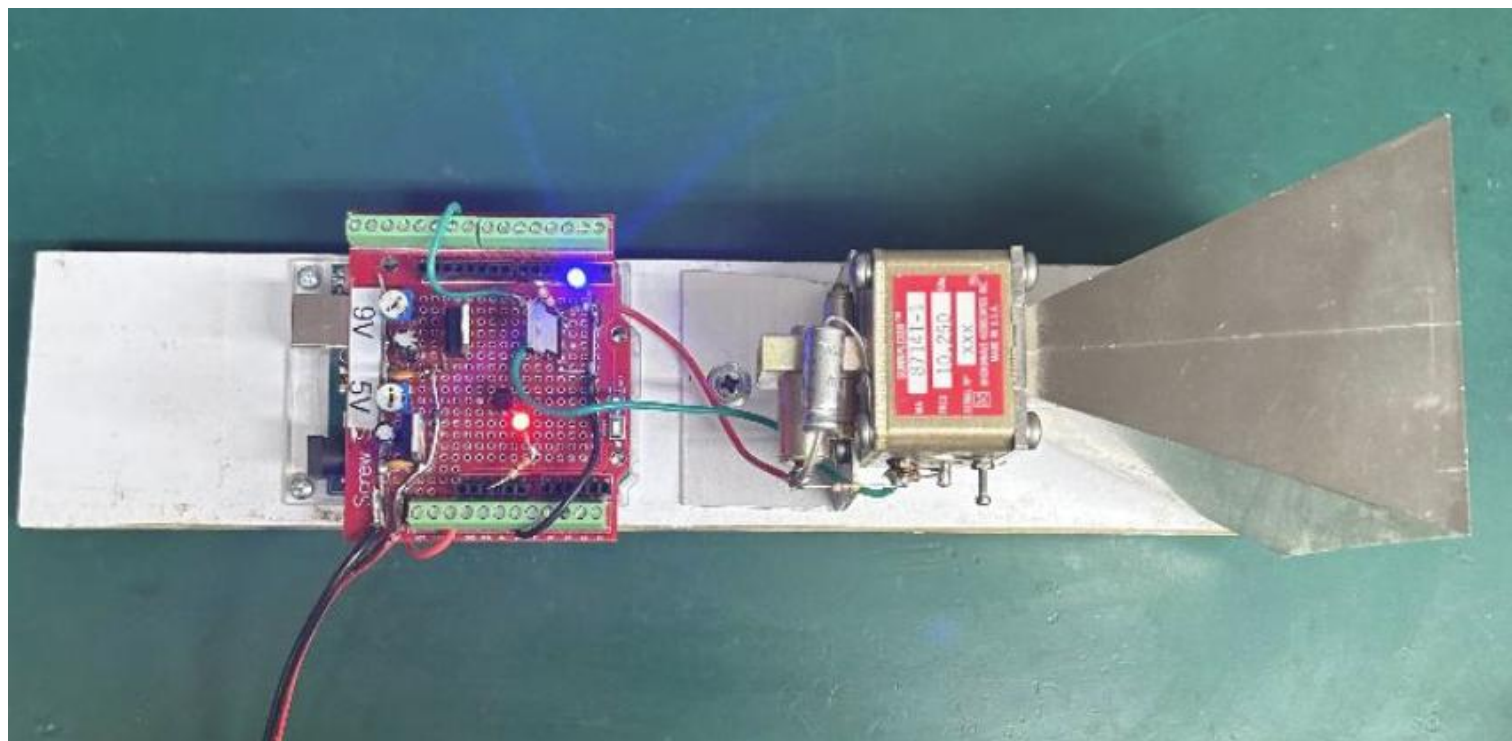
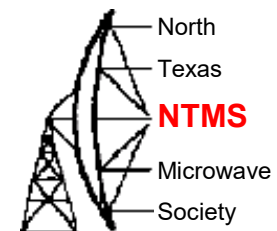
  OCR1A = 999; // 16MHz / (2*8*(999+1)) = 1000 Hz
  TCCR1B |= (1 << WGM12); // CTC mode
  TCCR1B |= (1 << CS11); // prescaler = 8
  TCCR1A |= (1 << COM1A0); // toggle OC1A on compare match
  interrupts(); return to normal
}

void loop() {
  // nothing to do - the timer runs the output in hardware
}
```

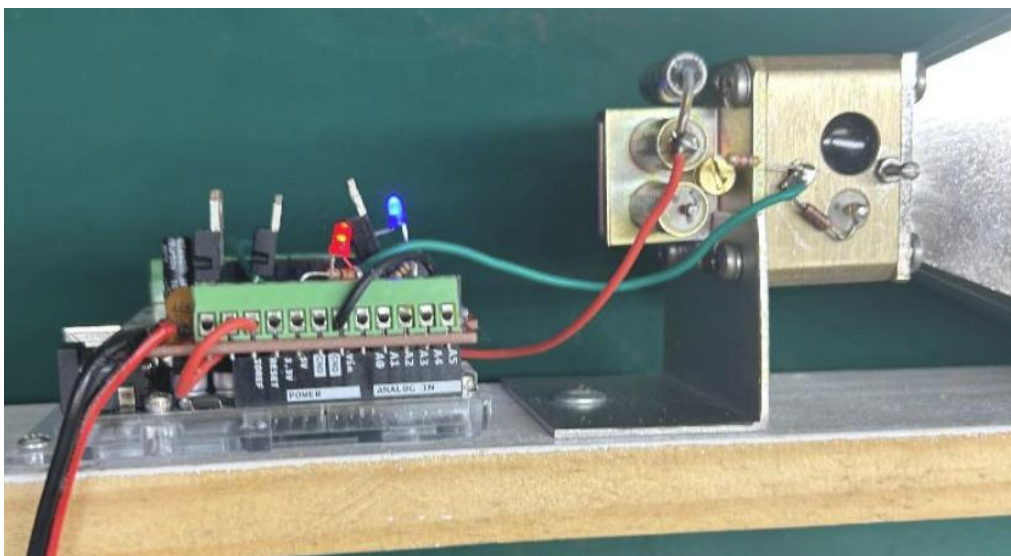
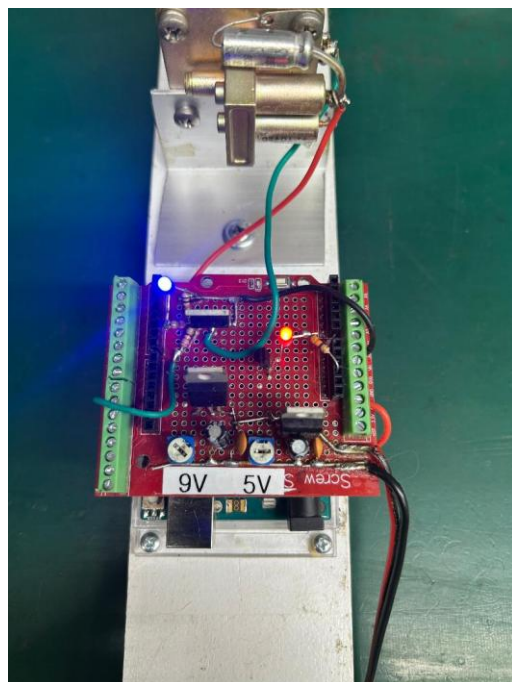
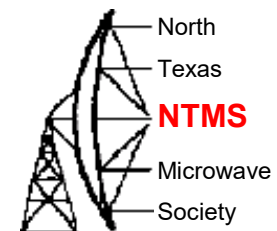
Timer register writes

- Timer1 hardware CTC toggle vs. bit banging loop.
- Dedicated hardware
- Driven straight from crystal/resonator counts
- Resets automatically
- Not in the “loop”

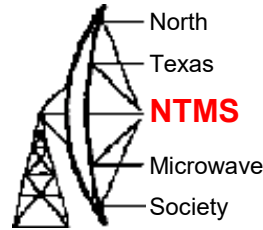
Completed unit



Completed unit

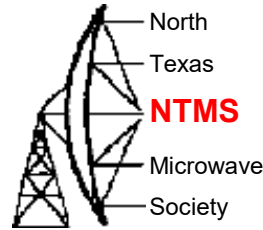


Power it up



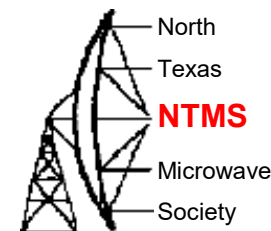
- **10 GHz output being detected** – using SA and diode detector. Frequency was approx. 10,225 MHz.
- **Confirm HP415E is detecting 1 KHz signal** – meter movement fluctuates in relation to signal strength input to crystal detector/load resistor
- **Check the power switching waveform through the MOSFET to Gunnplexer** — oscilloscope traces
- **Validate linearity**
 - Initially use attenuators (Service Manual procedure)
 - Set up antenna range and test 10 GHz antennas

Roads not taken



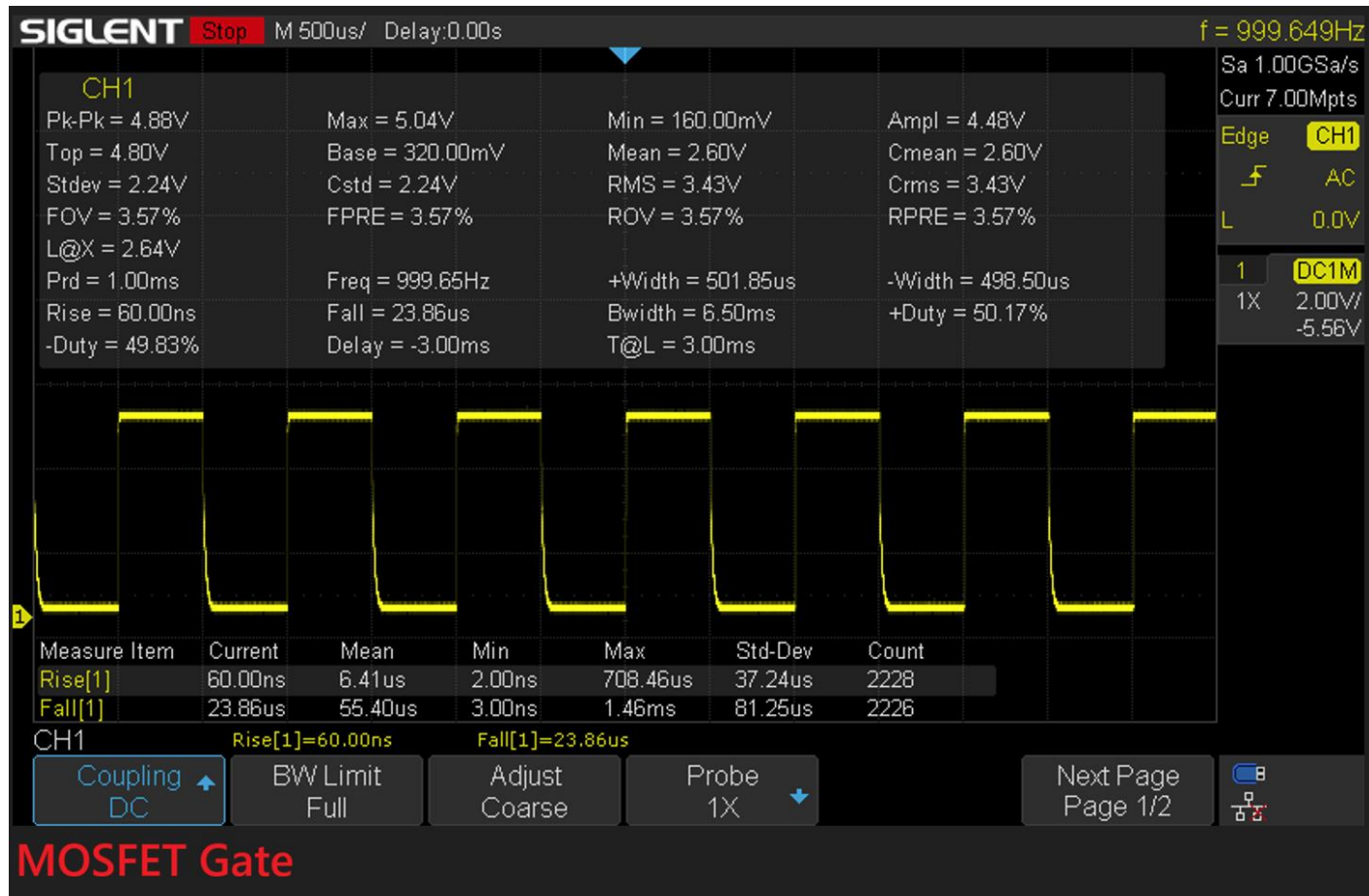
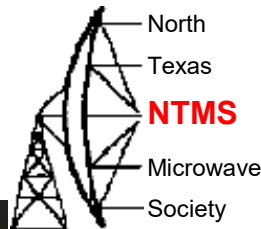
- **PIN diode in the waveguide/cavity**— varies waveguide loss directly via RF impedance modulation rather than touching the bias supply at all. Pro: doesn't load the Gunn diode's DC characteristics, often faster/cleaner edges. Con: needs the PIN diode and its own drive circuit, physically intrudes into the waveguide.
- **Mechanical chopper** (a motor-driven slotted disk interrupting the beam, or a vibrating reed) — genuinely old-school, predates solid-state modulation entirely. Pro: dead simple concept, no electronics touching the RF source at all. Con: mechanical wear, limited/imprecise frequency control, audible noise, size.

Roads not taken



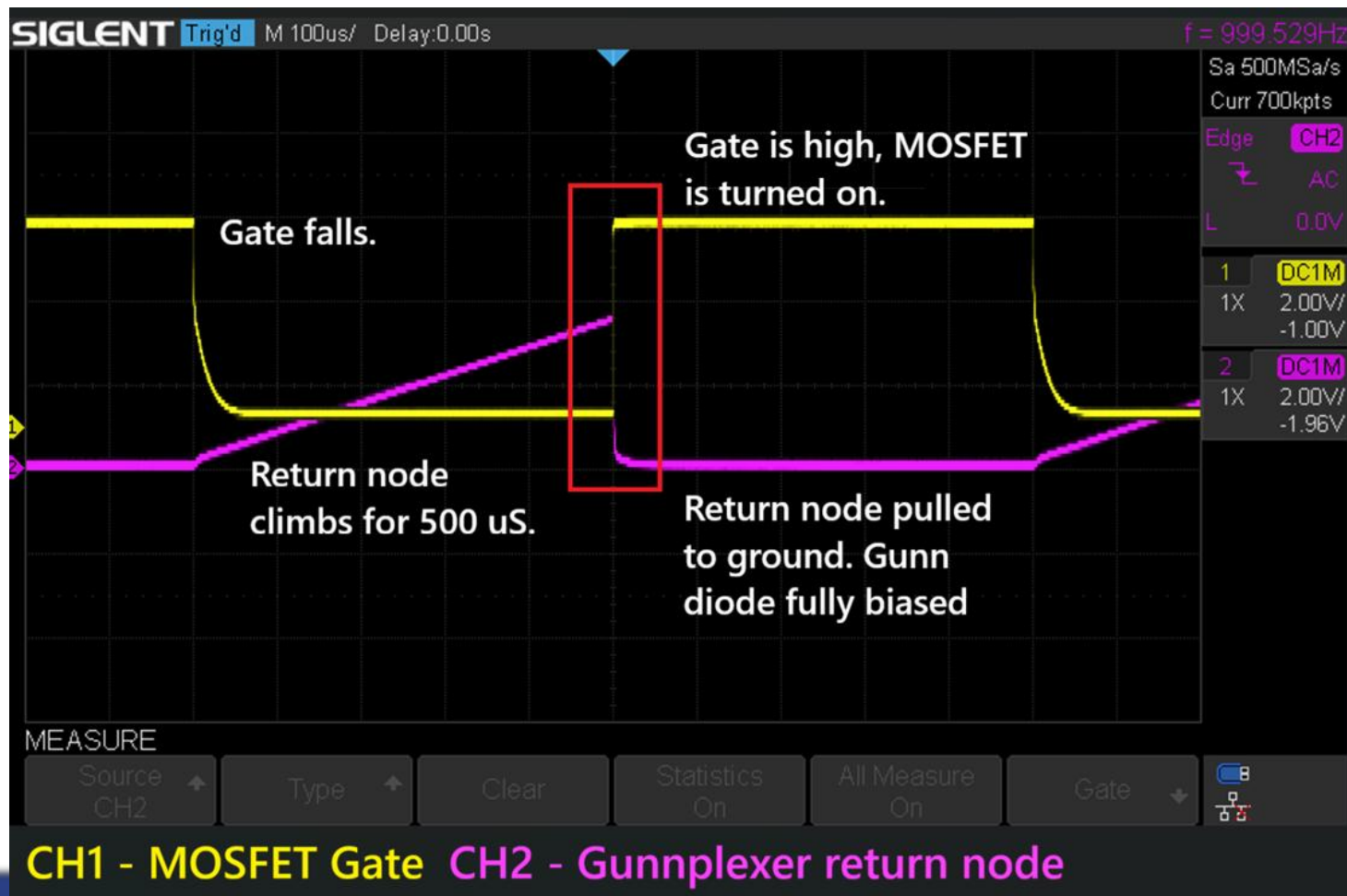
- **Direct bias modulation via a simple multivibrator or 555 timer** — chop the Gunn supply but without a microcontroller — an astable 555 could produce a similar square wave but the *frequency stability* point: a 555's RC-timed oscillation drifts with temperature and component tolerance, where the Timer1/crystal-referenced approach doesn't — a concrete, measurable advantage shown with scope data: 995-1000Hz, repeatably, across dozens of captures.
- **Varactor/voltage tuning port** for FM rather than AM — different modulation type entirely, not a fair substitute for what is needed, but worth a mention for completeness.

MOSFET gate trace

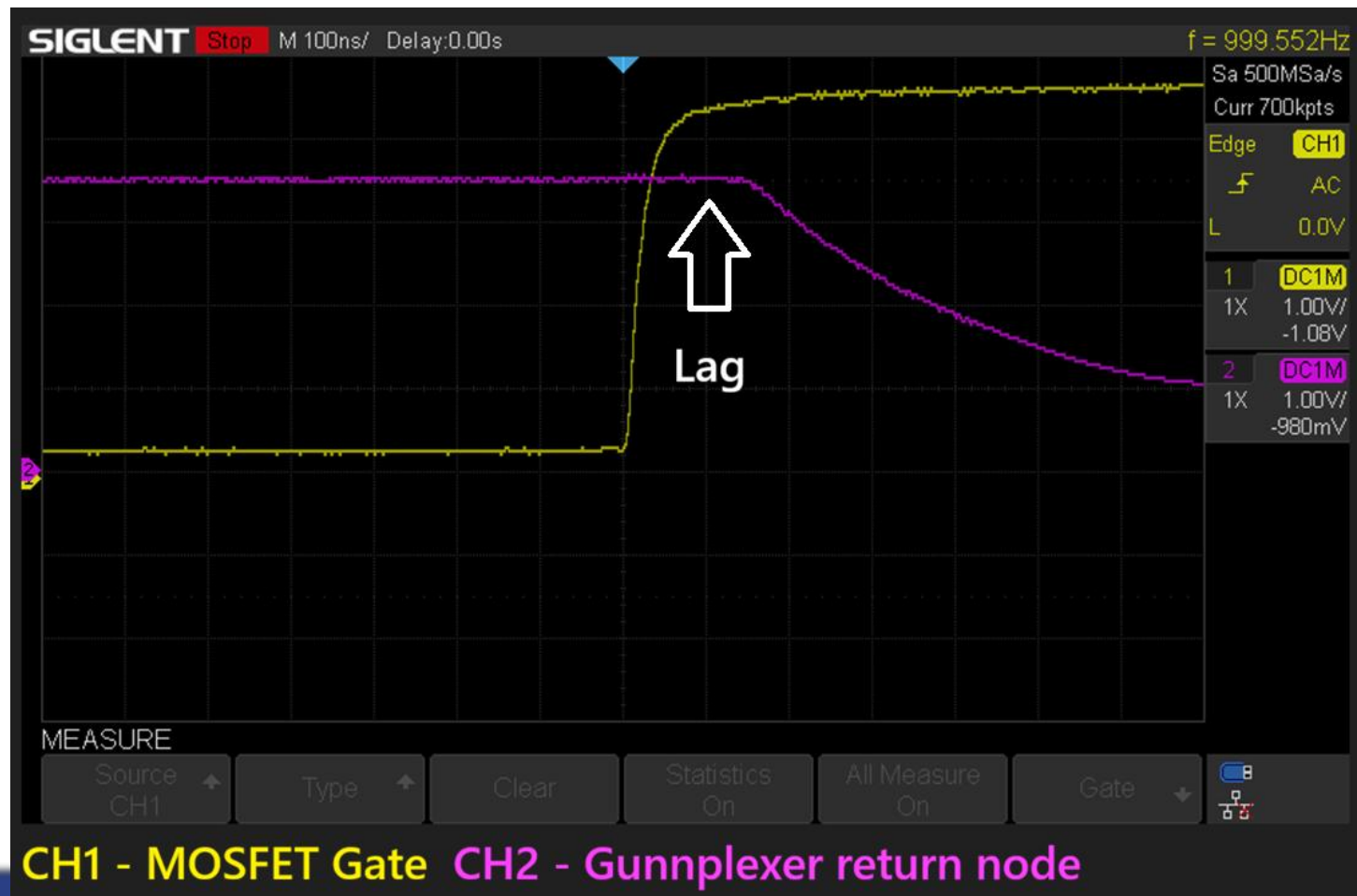


Hardware timer output: 5 V logic, 50% duty, 999.65 Hz, no CPU involvement.

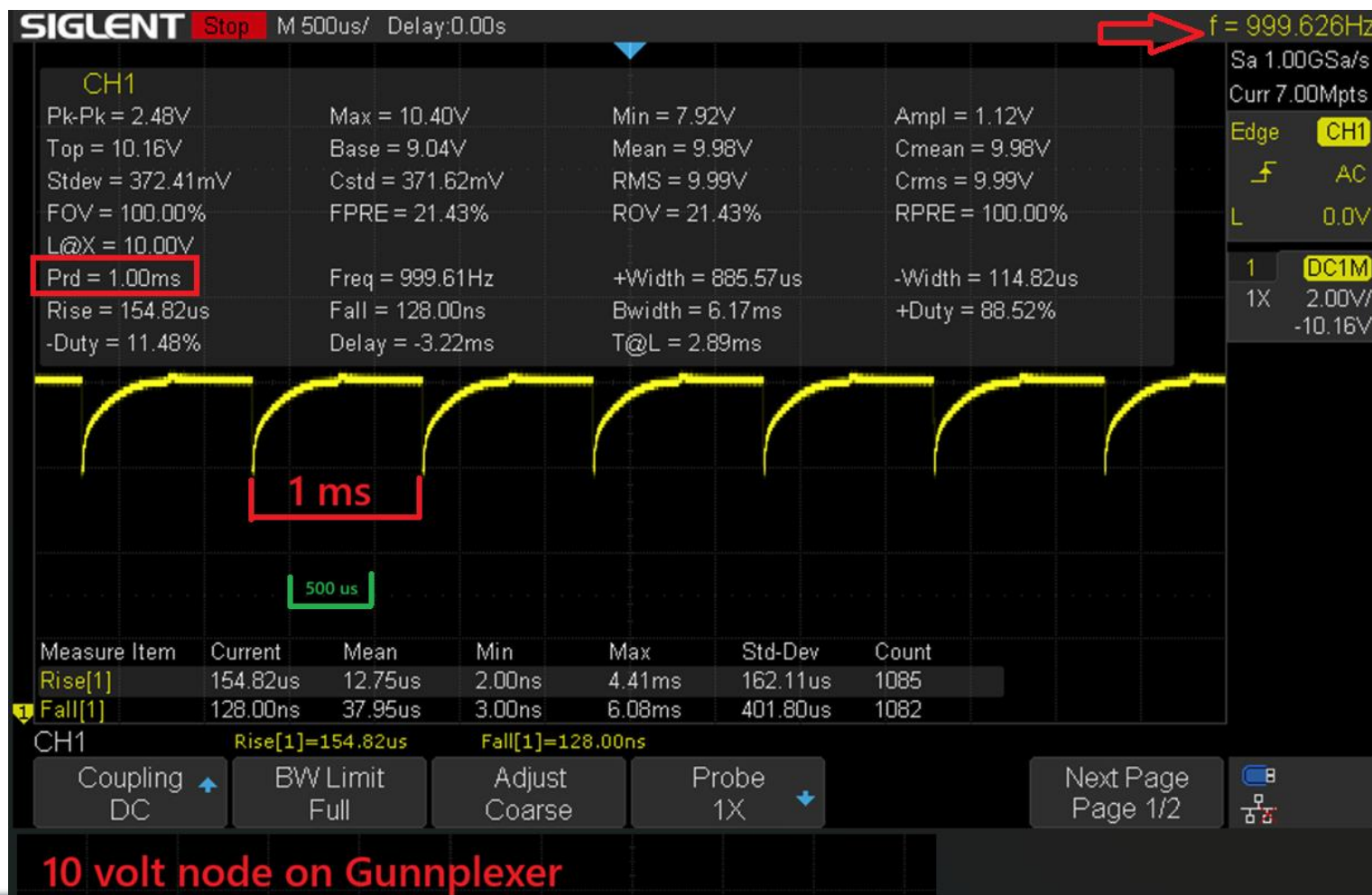
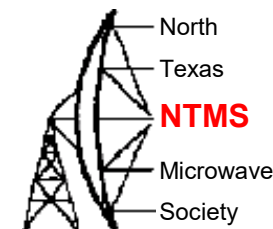
MOSFET gate vs Gunnplexer return node



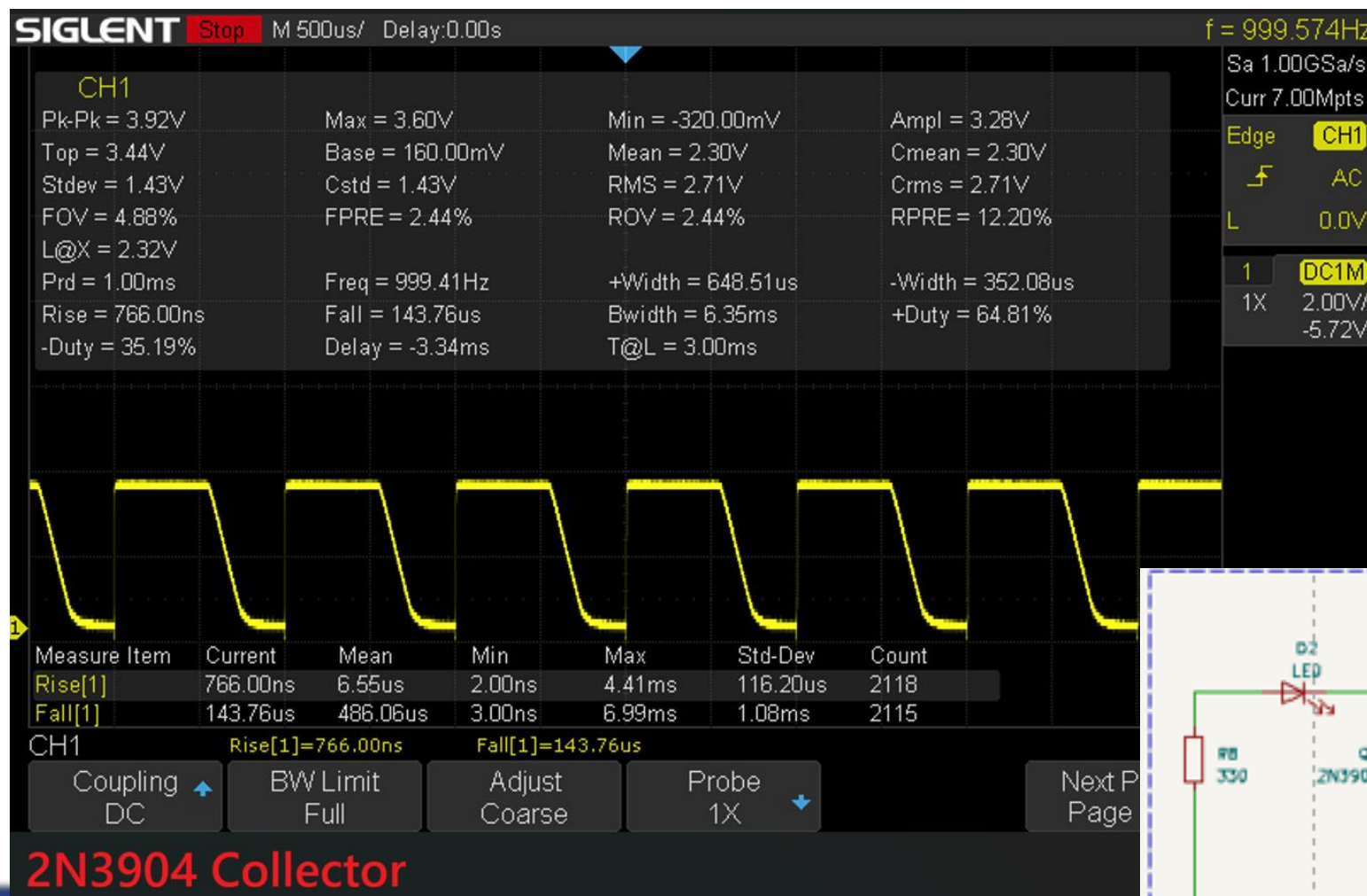
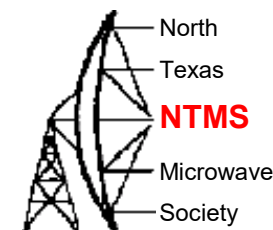
MOSFET gate vs Gunnplexer return node ZOOMED



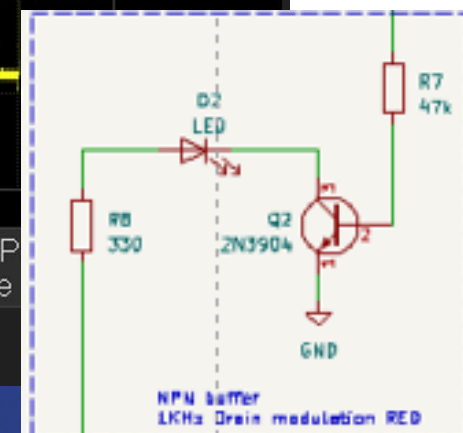
10 volt Gunnplexer node



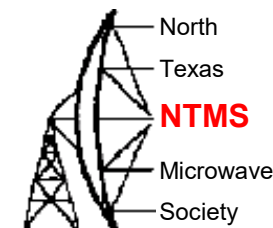
Optional NPN buffer circuit trace



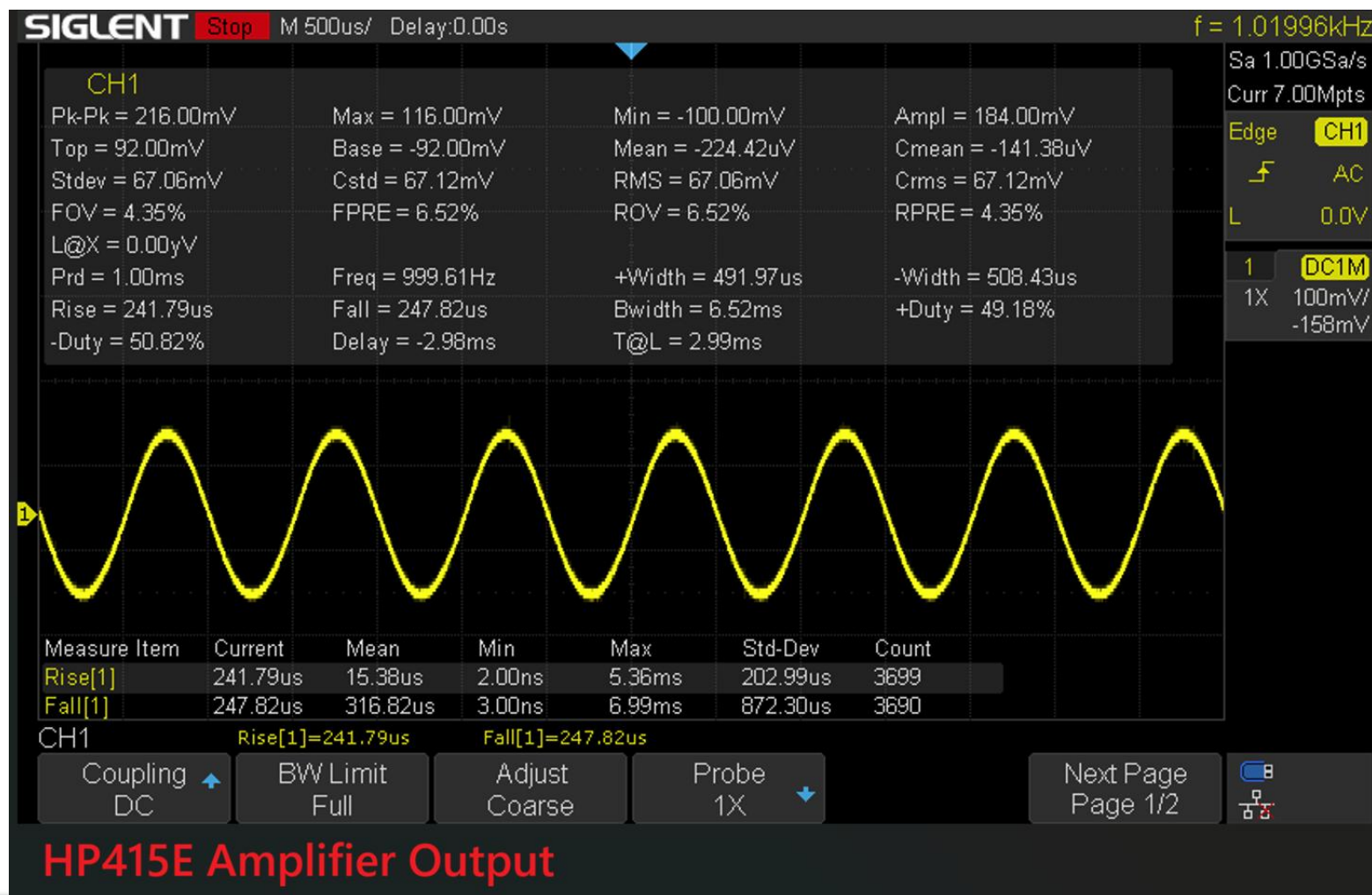
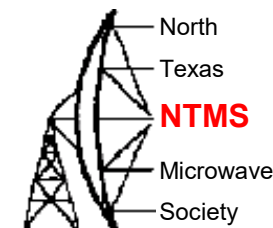
2N3904 Collector



Scope



Scope



The HP415E SWR Meter

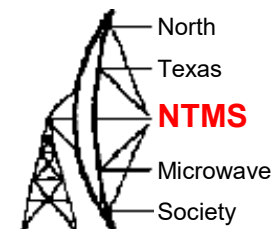


Fig. 1. New -hp- Model 415C SWR Meters being used in swept-frequency set-up to check directional coupler performance on broadband basis. Variable bandwidth of new SWR Meter permits sweep rates fast enough to achieve continuous oscilloscope display. New Meter is transistorized and has no-blind-spot "expand" feature to facilitate high-resolution attenuation measurements.

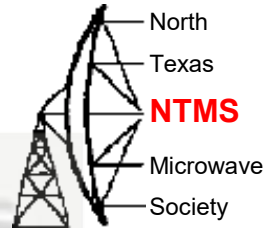


HEWLETT-PACKARD JOURNAL

TECHNICAL INFORMATION FROM THE -hp- LABORATORIES

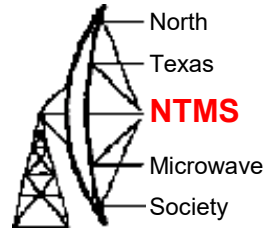
Vol. 13, No. 1-2

The HP415E SWR Meter



- An audio device.
- AC voltage voltmeter.
- Narrow bandwidth with a 1 KHz bandpass filter.
- High gain amplifier with relative gain controls.
- Requires other equipment to actually measure SWR.

The HP415E SWR Meter

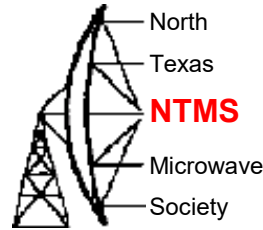


- Requires a 1 KHz audio signal at input.
- This can be produced by a crystal detector demodulating an RF signal.
- The crystal detector along with a load resistor operates on the square-law principle which the HP415E is designed to use.
- The Meter does not deal with RF.
- The crystal detector covers a range of RF frequencies.

Crystal detectors



Square law



- A crystal detector follows a square-law response at low input power levels - (typically below -20 dBm or 10 uW), whose output voltage is proportional to the square of the input signal amplitude.
- This behavior comes from the nonlinear I–V characteristic of the diode operating in its nonlinear region.
- A square law graph plots output voltage (or current) versus input signal amplitude (or power).
- Curve shape: For small input amplitudes, the curve is quadratic, so it rises steeply with the square of the input amplitude.

Typical response²

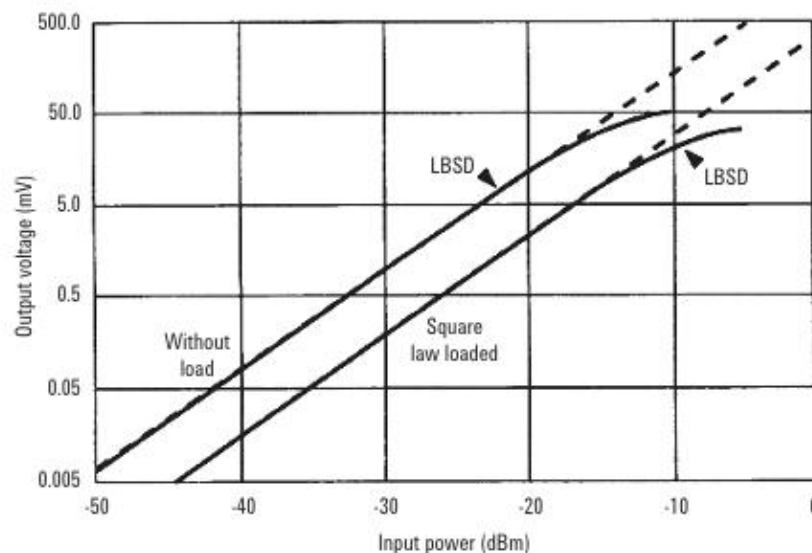
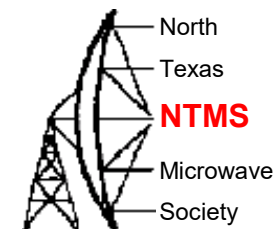


Figure 6. Typical detector square-law response

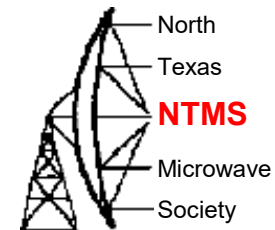
Square-law response

For many reflection and transmission measurements it is desirable to use the detector in its square-law region where its output voltage is proportional to the input RF power. As shown in figure 6, the LBSD typically operate within 0.5 dB of square-law from the tangential signal sensitivity (TSS) level up to -18 dBm.

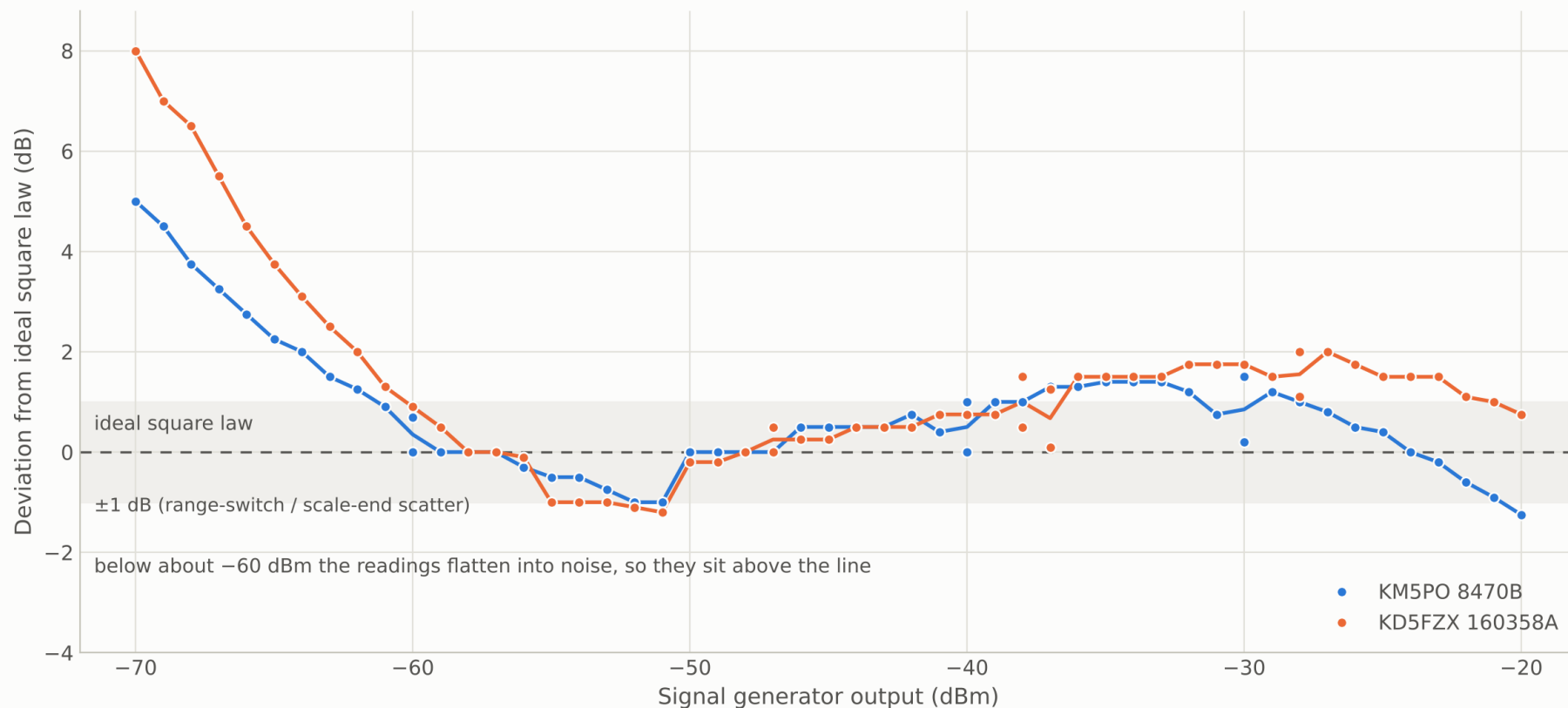
By specifying Option 423B, 847xB/C-002, a specially selected loading resistor is provided which extends this square-law region to approximately 8 dB with an associated decrease in sensitivity as shown in figure 6.

Actual response

Tested on my bench



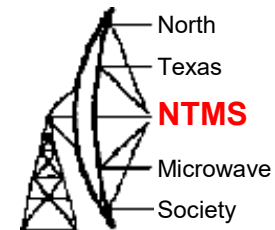
Where the detectors leave the square-law line



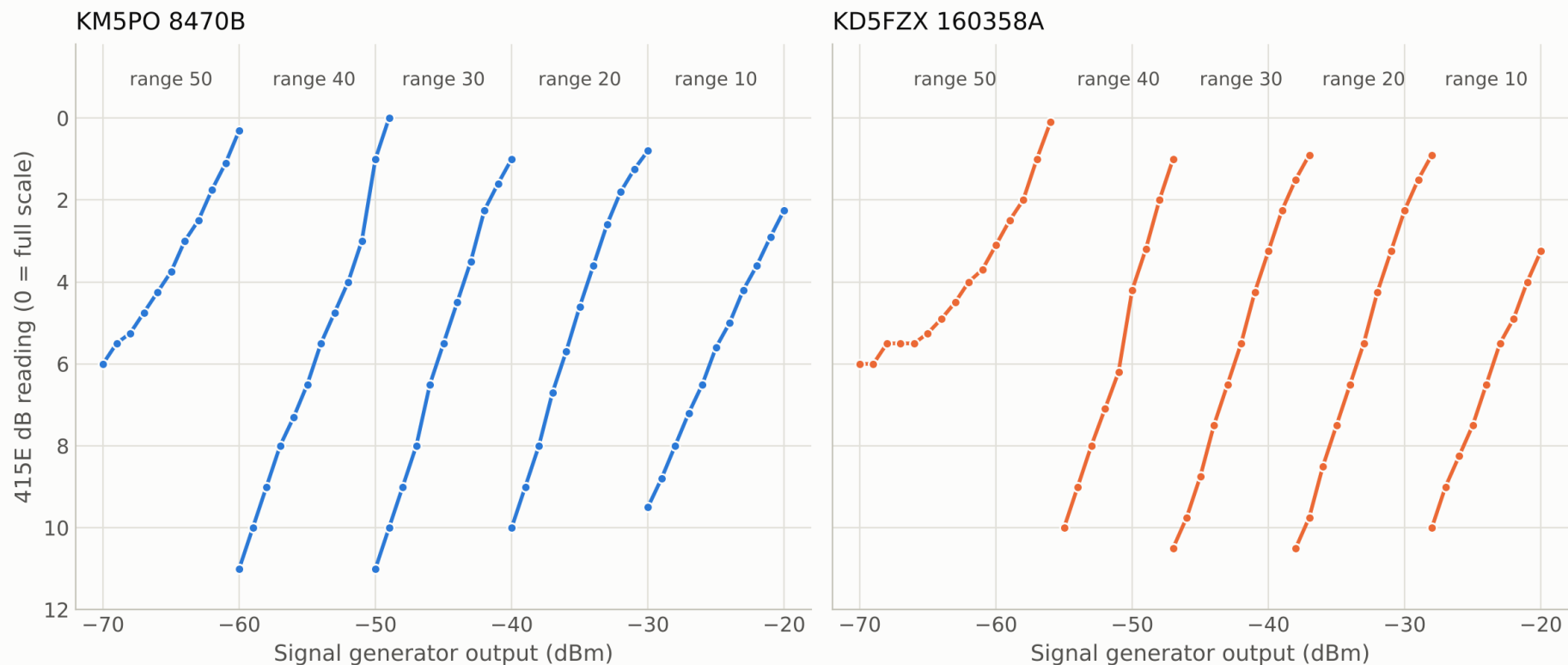
Ideal line: slope 1 dB/dB, anchored to each detector's median level from -40 to -58 dBm.

Actual response

Tested on my bench



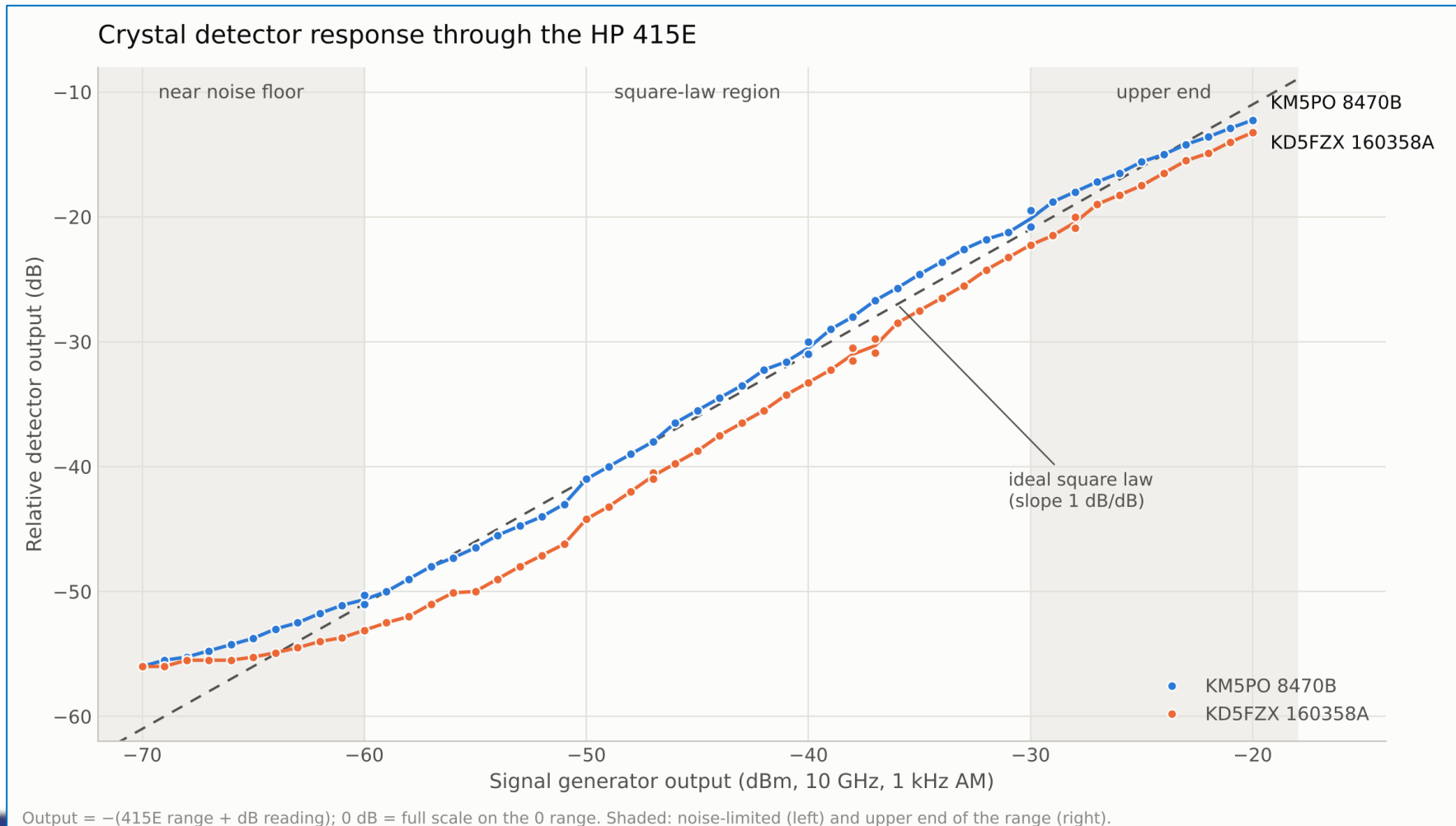
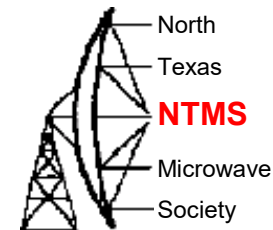
Raw meter readings: each range gives a short straight segment



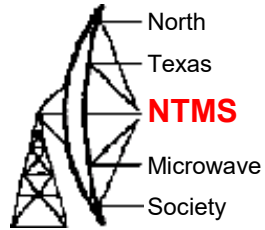
Each 10 dB range step re-zeros the meter, so the raw data looks like a sawtooth. Adding the range back (Figure 1) joins the segments.

Actual response

Tested on my bench



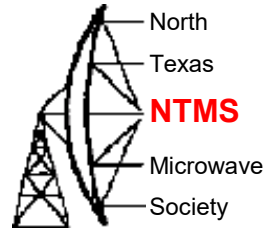
Full test procedures



The service manual details the following tests:

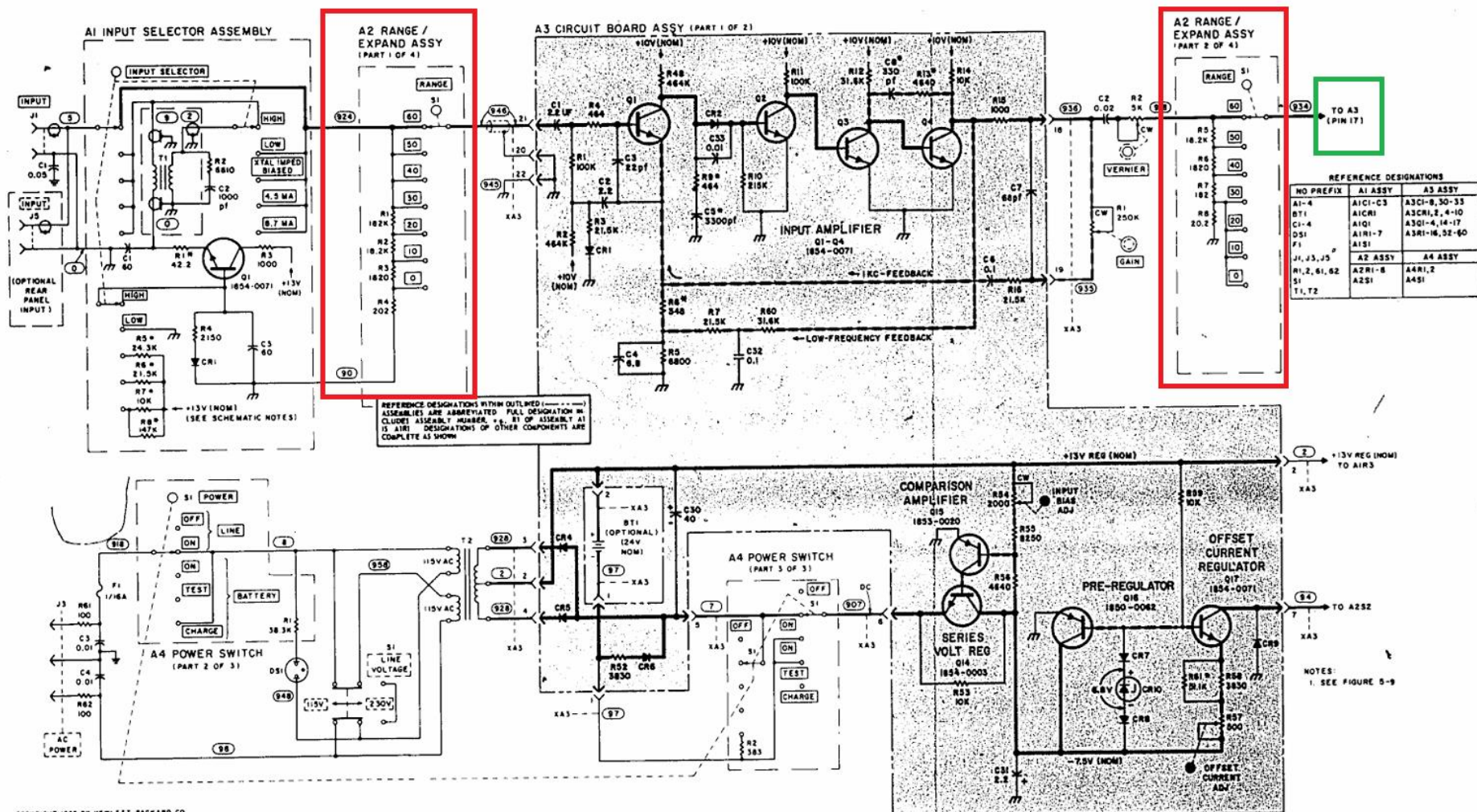
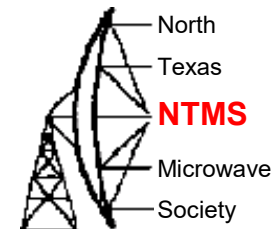
- Sensitivity
- Noise
- Range accuracy
- Expanded range accuracy
- Input frequency
- Bandwidth

RF dBs vs Voltage dBs

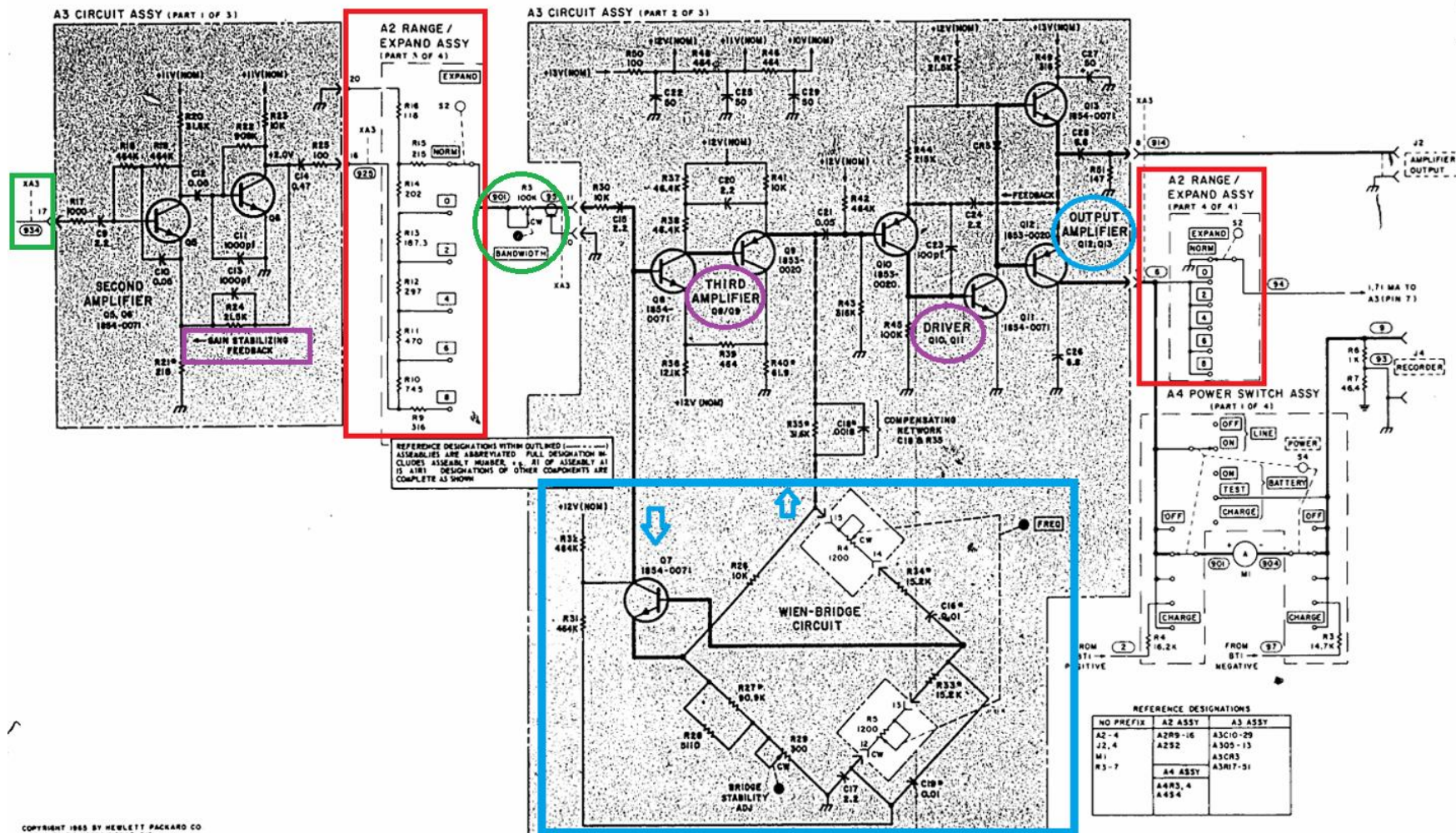
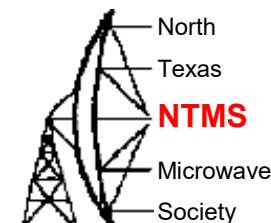


- **With a 1 kHz voltage applied directly to the input** (audio oscillator, no detector), the voltage must change by 20 dB, a 10:1 ratio, to move the meter 10 dB.
- **With RF through a square-law detector**, a 10 dB RF change moves the meter 10 dB.
- **The range dial is marked 0 to 60 in 10 dB steps, which translates to 0 to 120 dB of voltage gain at 1 kHz. Each dial step adds 20 dB of voltage gain ($\times 10$).**
- **Audio test:** feed a 1 kHz sine wave from an audio oscillator straight into the input, approx. 5 V peak to peak. Adjust the audio oscillator gain for a full-scale (0 dB) reading. Add 10 dB of attenuation, a voltage ratio of 0.316. The meter reads 5 dB.

HP415E schematic pt 1

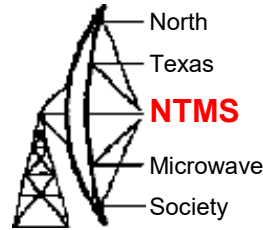


HP415E schematic pt 2





Wien-bridge history at HP



1891: Max Wien invents the bridge for measuring impedance. Its R-C network has a phase shift that passes through zero at exactly one frequency.

1938: Larned Meacham uses a light bulb to stabilize a bridge oscillator. This is the precedent.

1938 to 1939: Bill Hewlett applies the bulb to a Wien-bridge audio oscillator, which becomes the HP 200A. It's built in David Packard's Palo Alto garage and is HP's first product. The circuit is the subject of Hewlett's 1939 Stanford thesis and HP's first cited patent (US 2,268,872). The 1939 IRE paper is credited to Terman, Buss, Hewlett and Cahill.

1939 to 1940: Disney buys eight custom 200Bs for the sound of Fantasia.

1950s to 1990s: The 200CD (5 Hz to 600 kHz) becomes a standard lab instrument.

1960s: The same bridge idea goes into the 415 SWR meters. My 415E schematic is copyrighted 1965.

The HP-200B

A Deal with Disney: HP 200B Oscillator


[ENLARGE](#)
[SHARE THIS PIECE OF HISTORY](#)


Date: ca. 1939

Modified versions of Hewlett-Packard's 200A oscillator for specific applications went into production almost simultaneously with the 200A itself. Perhaps the most famous modification was the 200B, a custom-designed product for Walt Disney Company. Disney ordered eight of them for use in the audio production of *Fantasia*, most famously in the installation of Fantasound, a pioneering surround sound system Disney placed in select theaters for the film's release. It was the beginning of a working relationship with Disney that would continue throughout Hewlett-Packard's history.

TAGS:

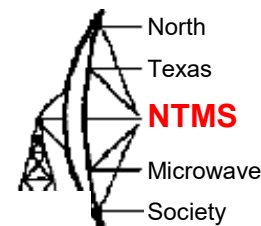
1930S • 1939 • 200B • DISNEY • FANTASOUND • FILM • OSCILLATOR

(C) HPCA



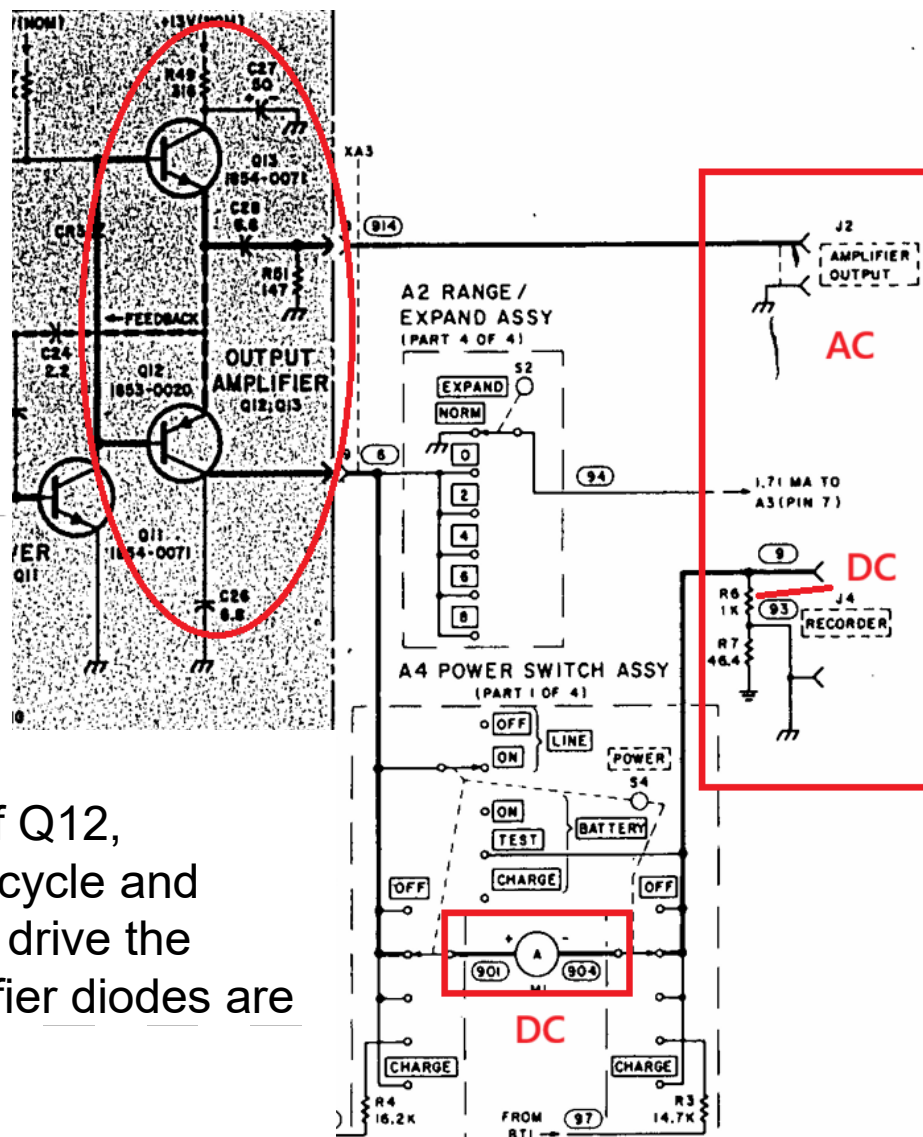
Disney HP 200B and Fantasia

AC and DC outputs



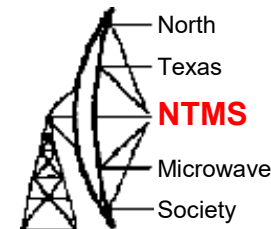
Class B push-pull.

Q12 and Q13 conduct one at a time on alternate half-cycles. The AC tone is the composite of both cycles tied to the joined emitters through coupling cap C28 and developed over R51.



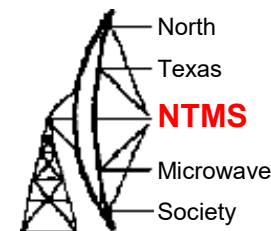
The collector current of Q12, conducting on the half cycle and smoothed by C26, can drive the meter directly. No rectifier diodes are needed.

Setting up the Microwae Range³



1. Place the source antenna (horn or similar) on the ground, with cardboard, Eccosorb, or another non-reflective material underneath.
2. Connect the signal generator to the source antenna and configure the power source as needed.
3. Configure the signal generator:
 1. Frequency: 1296.100 MHz
 2. Output: 10 dBm
4. Position the receive reference antenna approximately 100 feet from the source.
5. Connect the detector diode and attenuator to the receive reference antenna.

Setting up the Microwave Range³



6. Use the HP415E to verify a flat field (≤ 1 dB variation) at the receive end.

- Mark the center of the field on the ground.

7. Record the baseline reading (approximately -2 dB on the -30 dB scale). **Objective: Standard horn and AUT gain within 10 dB ish.**

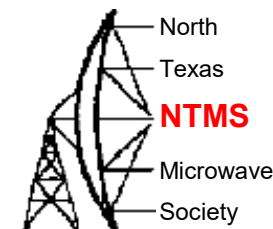
8. Replace the reference antenna with the antenna under test.

- Move the antenna up/down and left/right to obtain peak reading.
- Do not move forward or backward remain at the marked ground location.

9. Calculate gain relative to the reference antenna.

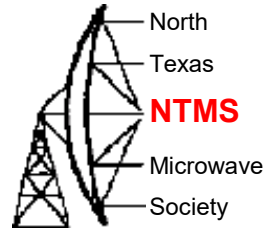
10. Record the results.

Example range path losses



Frequency	Distance	Path Loss
902 MHz	100 ft	61.23 dB
1296 MHz	100 ft	64.38 dB
2304 MHz	100 ft	69.38 dB
3400 MHz	100 ft	72.76 dB
5760 MHz	100 ft	77.34 dB
10368 MHz	100 ft	82.44 dB
24192 MHz	100 ft	89.80 dB
47088 MHz	100 ft	95.59 dB
76032 MHz	100 ft	99.75 dB
122350 MHz	100 ft	103.88 dB

Example range calculations



Microwave example (10368 MHz)

Source transmit power: +10 dBm

Source horn gain: +15 dB

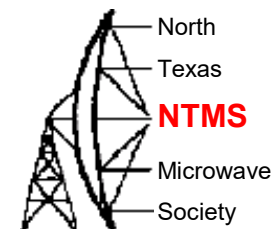
EIRP: +25 dBm

Path loss: -88.44 dB = Received power -63.44 dBm

Receive antenna gain (AUT): +30 dB (previously measured value)

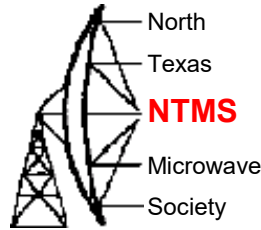
Final received level: -33.44 dBm

Example range calculations



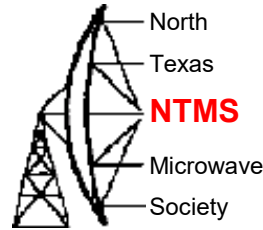
Using the previous result	
(Known) Reference horn gain	20 dB
(Set) Reference level at HP415E	2 dB on 30 dB scale
Replace Ref horn with AUT	
HP415E receive level of AUT	2 dB on 20 dB scale (requires switching dB scale knob)
AUT calculated gain	Ref 20 dB +10 dB = 30 dB

Next steps



- Add 24 GHz capability
- Add a useful VHF band capability. 1296 MHz?
- Create a standard Gunnplexer modulation PCB board
 - Research alternative PICs (ATTINY85, others)
- Use KiCad to create gerbers, order boards

References



1. The Gunnplexer Cookbook by Bob Richardson W4UCH/2, 1981 (see KM5PO if you need a copy)
2. Keysight 423B, 8470B, 8472B, 8473B/C Low Barrier Schottky Diode Detectors – Data Sheet,
https://xdevs.com/doc/HP_Agilent_Keysight/5952-8299%20423B,%208470B,%208472B,%208473B%20C%20Low%20Barrier%20Schottky%20Diode%20Detectors%20-%20Data%20Sheet%20c20140715%20%5B6%5D.pdf
3. Central States VHF Society Proceedings - Central States VHF Society Antenna Range Procedures Antenna Range Procedures
Author: Kent O'Dell, KA2KQM Date: June 08, 2026
4. [HP 200A, Wikipedia](#)
5. [Wien bridge oscillator, Wikipedia](#)
6. [The 200-A: Hewlett-Packard's First Product, SMECC](#)
7. [HP 415E notes, prc68.com](#)
8. [HP Journal, September 1961](#)

Questions?

