Phase and Frequency Locking of Magnetrons by Pushing and Pulling

Imran Tahir
Lancaster University

This work is being supported by PPARC and E2V

Introduction

The idea of phase locking the magnetron is as old as magnetron itself. The concept of injection locking was introduced in early 50’s.

A problem with the application of injection locking is the requirement of a relatively high power and stable frequency source thereby adding considerable cost.

Relative Cost of Magnetrons and Klystrons

Tube	Power	Voltage	Freq.	Tube Cost	Power Supply Cost	Total Cost per kW
Klystron	250kW	50kV	500MHz	£200,000	£200,000	£1600
IOT	70kW	35kV	500MHz	£60,000	£40,000	£1430
Magnetron	100kW	18kV	900MHz	£30,000?	£40,000?	£700

A cost effective solution to magnetron phase locking is desirable

1 to provide a low cost substitute for Klystrons in certain particle accelerators applications.

2 to overcome load variation and moding problems in industrial applications.

3 for space power transmission applications

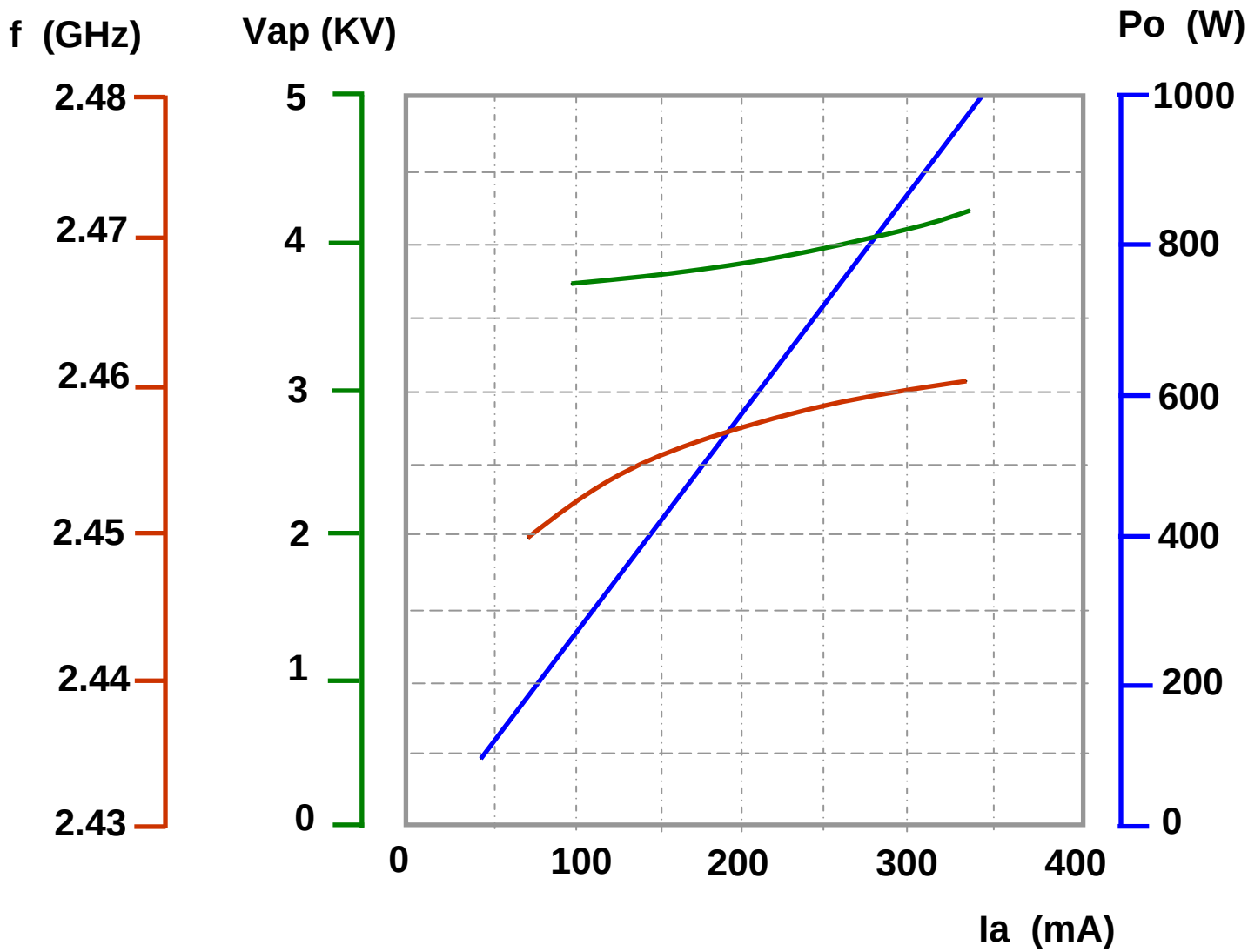
4 for phased array radar

Specification of Phase Stability for Particle Accelerators

- The microwave power sources for particle accelerators are required to have following phase stabilities,

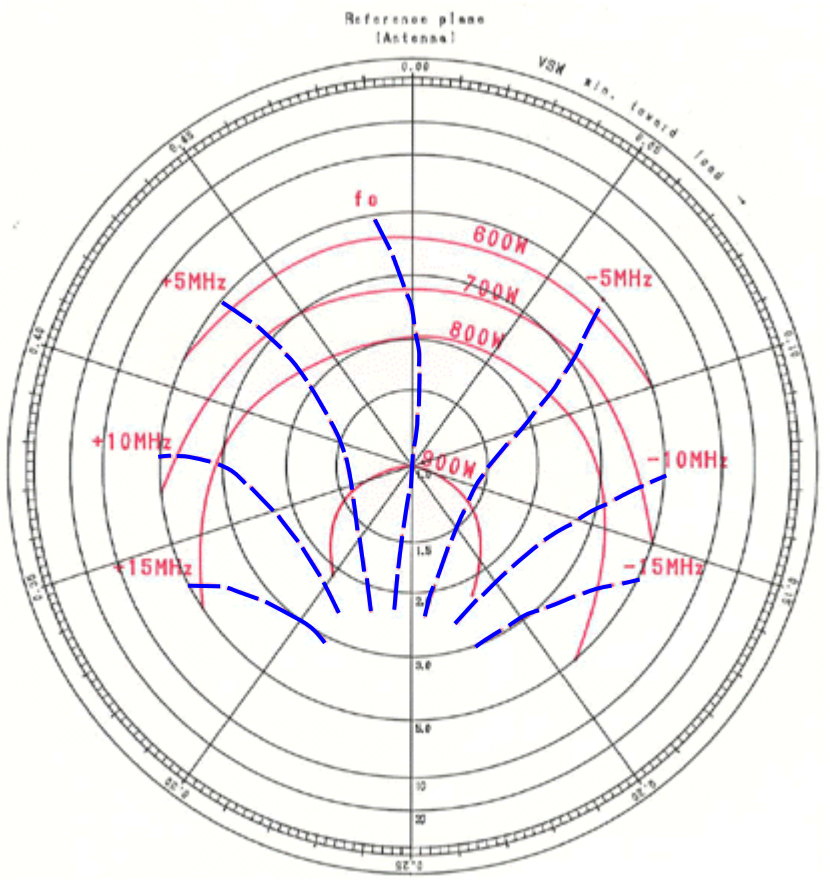
Proton Accelerators	1 -- 2 Degrees
Electron Accelerators	0.1 – 0.2 Degrees

PERFORMANCE GRAPH OF MAGNETRON



Pulling

- RIEKE DIAGRAM



Change in load reactance, changes the frequency. Change in frequency depends upon amount of power reflected and its phase.

Work which has been done

1- ***W.C. Brown***

An electronically steer able phased array module using the microwave oven magnetron with external circuitry as high gain phase locked amplifier.

Proc. First Int. Workshop on Crossed-Field devices, August 15-16, 1995

2- ***Noaki Shinohara, Hiroshi Matsumoto & kozo hashimoto***.

Solar Power Station/Satellite (SPS) with Phase Controlled Magnetrons.
(Kyoto University, Japan)

IEICE TRANS. ELECTRON, VOL. E86-C No.8 August 2003

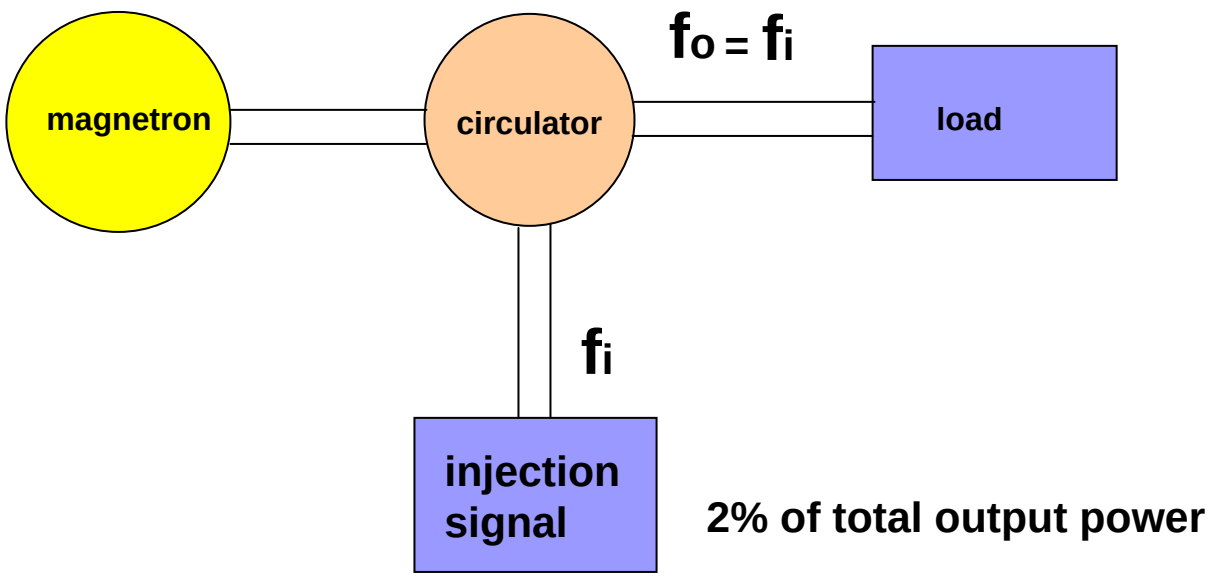
How Magnetron Can be Phase Locked

- 1- **INJECTION LOCKING**
- Injected signal into output cavity

- 2- **PHASE LOCKED LOOP**
- Measure phase/frequency and then using pushing and pulling characteristics to shift frequency so that phase can be driven back to correct point.

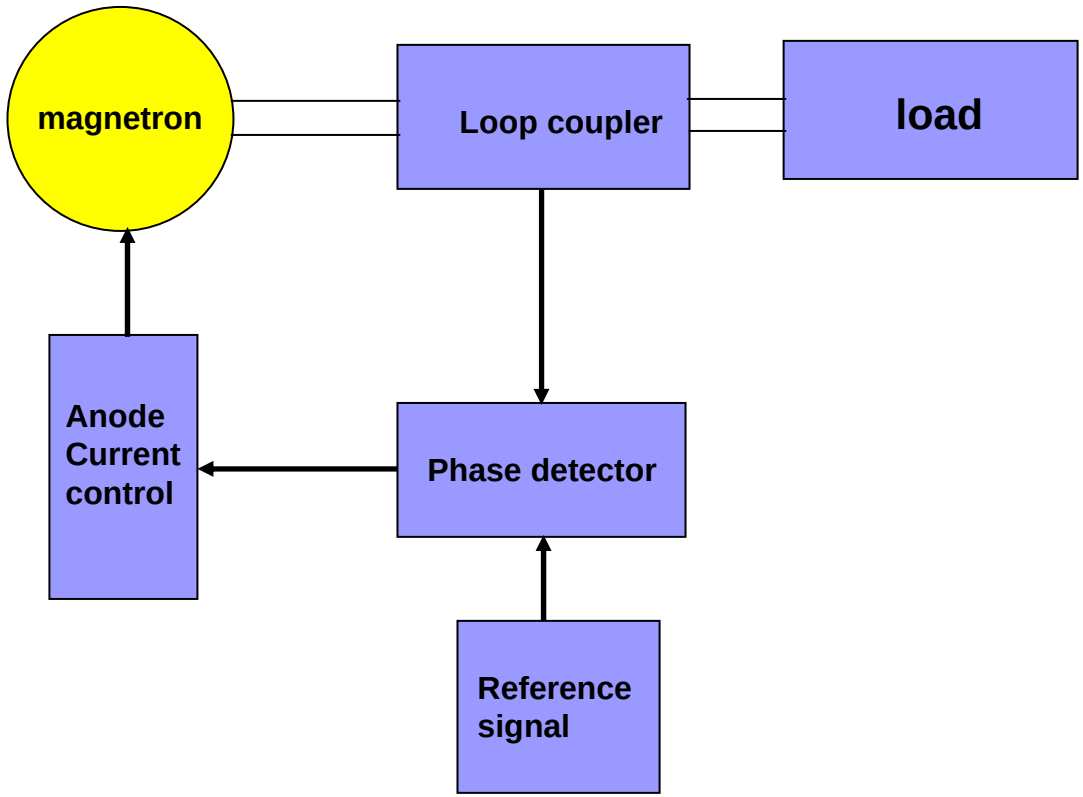
Injection Locking

- The level of injection signal depends on spectral BW of magnetron frequency. For a stabilized DC power supply, injection level equal to 2% of total output power is sufficient to lock.



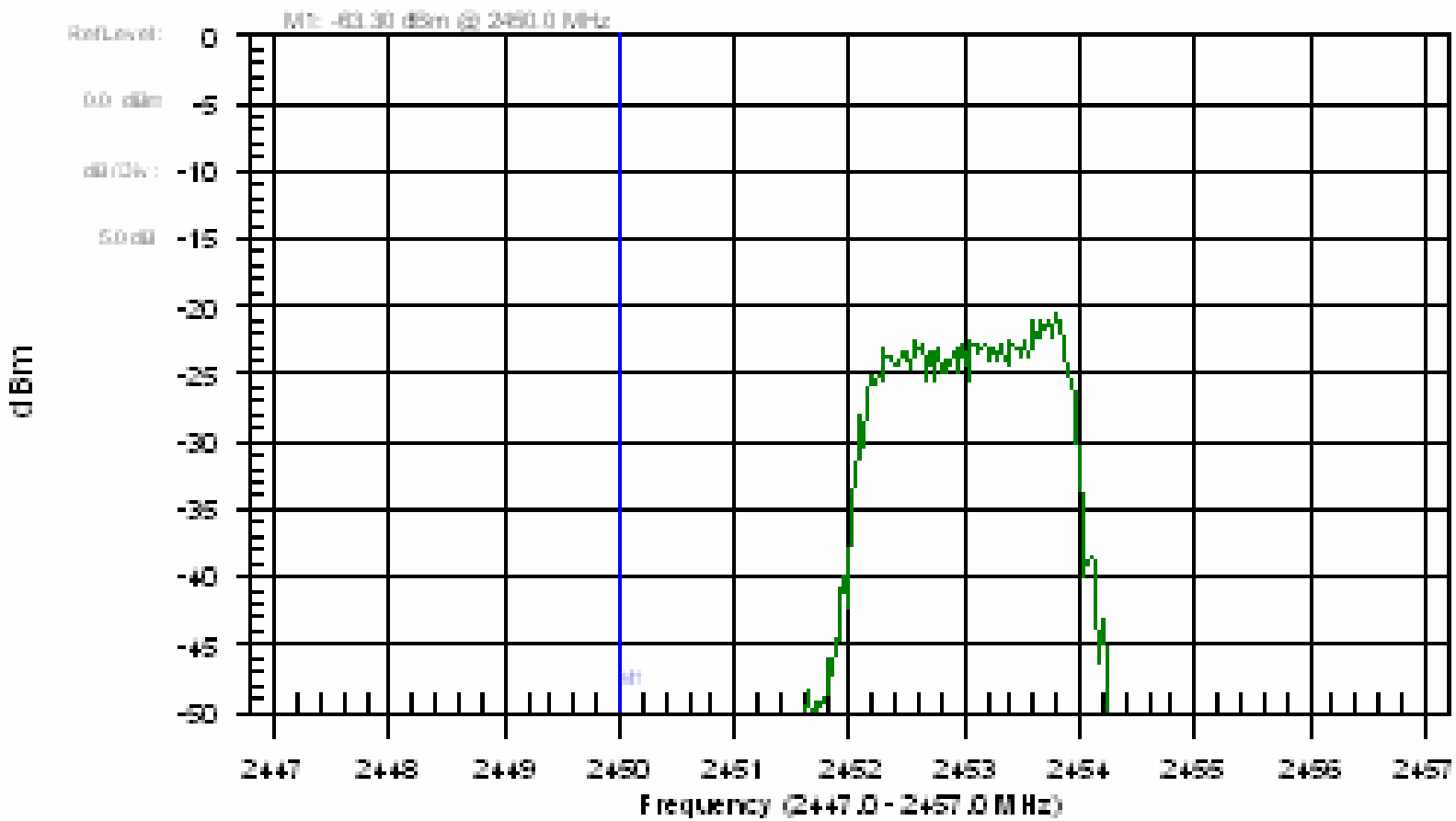
Phase locked loop method

- Error voltage from phase detector controls current through magnetron by changing Anode to cathode voltage.



Spectrum Analyzer

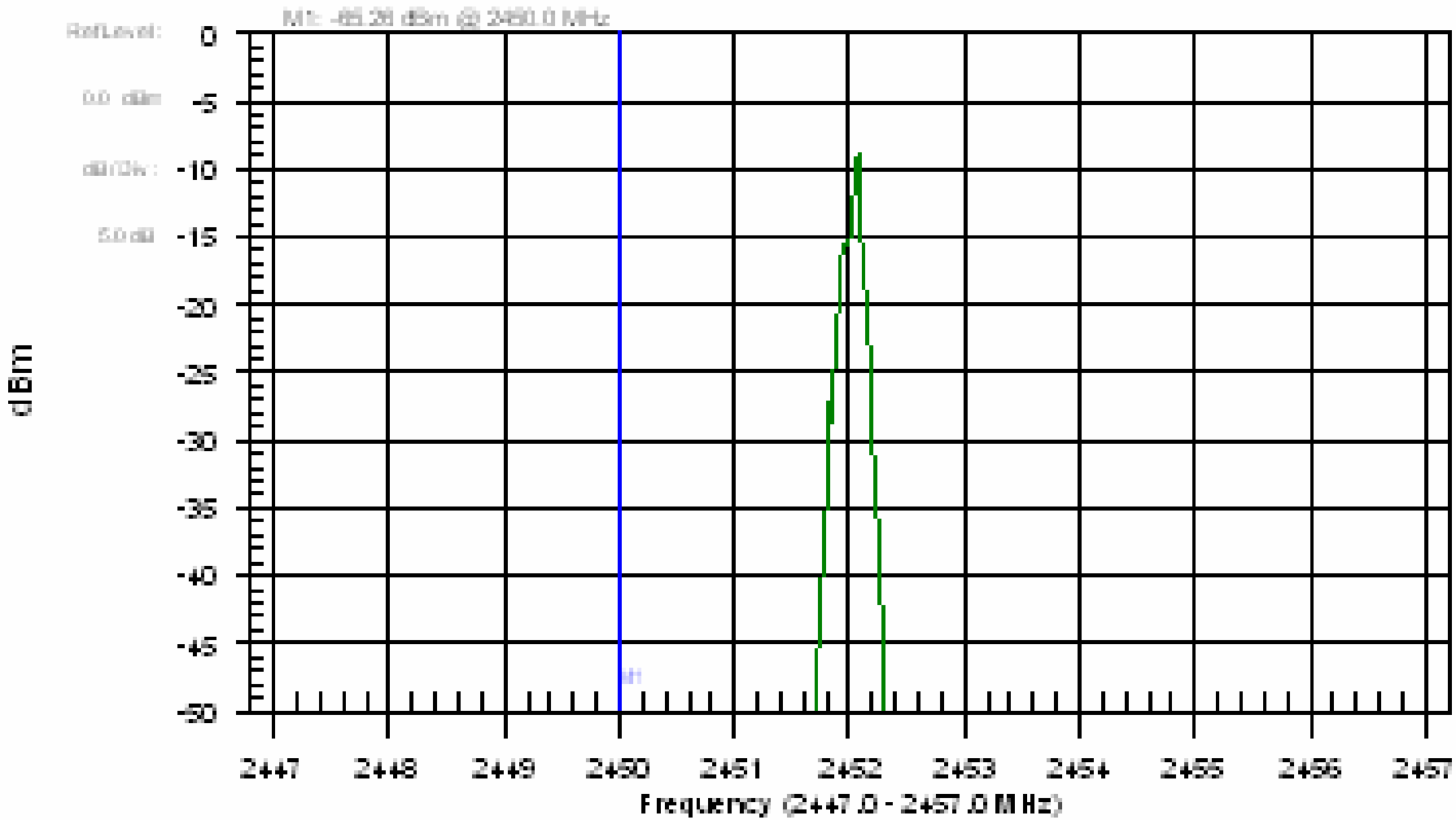
Filament Current 'ON'



CF: 2452.0 MHz
SPAN: 10.00 MHz
Attenuation: 31 dB
RBW: 10 kHz
VBW: 3 kHz
Detection: Pos. Peak
Min Sweep Time: 1.00 Milli Sec
Date: 03/29/2004
Time: 14:31:02
Average:5
Model: MS2711D
Serial #: 00403092

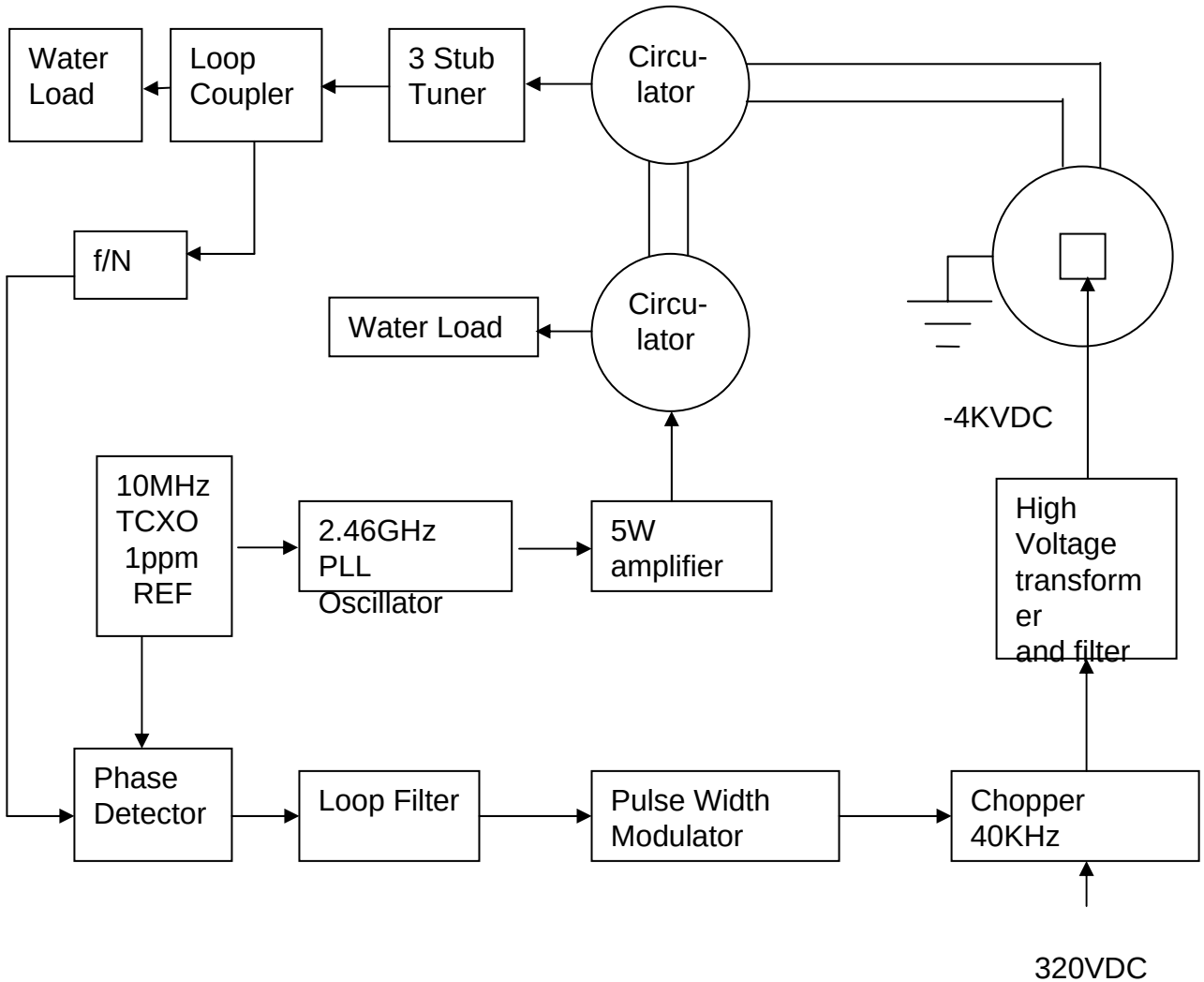
Spectrum Analyzer

Filament Current 'OFF'

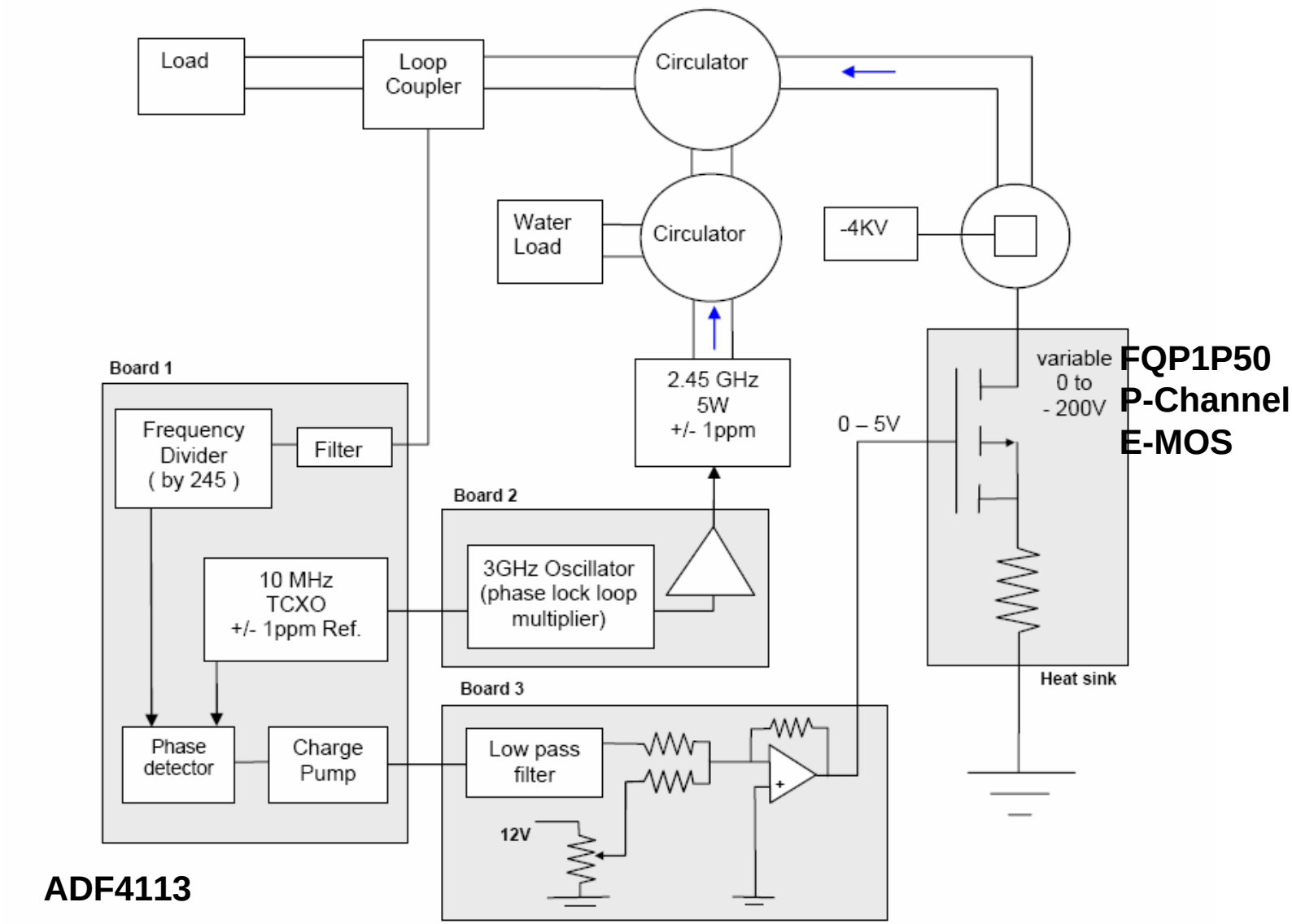


CF: 2452.0 MHz
SPAN: 10.00 MHz
Attenuation: 31 dB
RBW: 10 kHz
VBW: 3 kHz
Detection: Pos. Peak
Min Sweep Time: 1.00 Milli Sec
Date: 03/29/2004
Time: 14:30:31
Average:5
Model: MS2711D
Serial #: 00403092

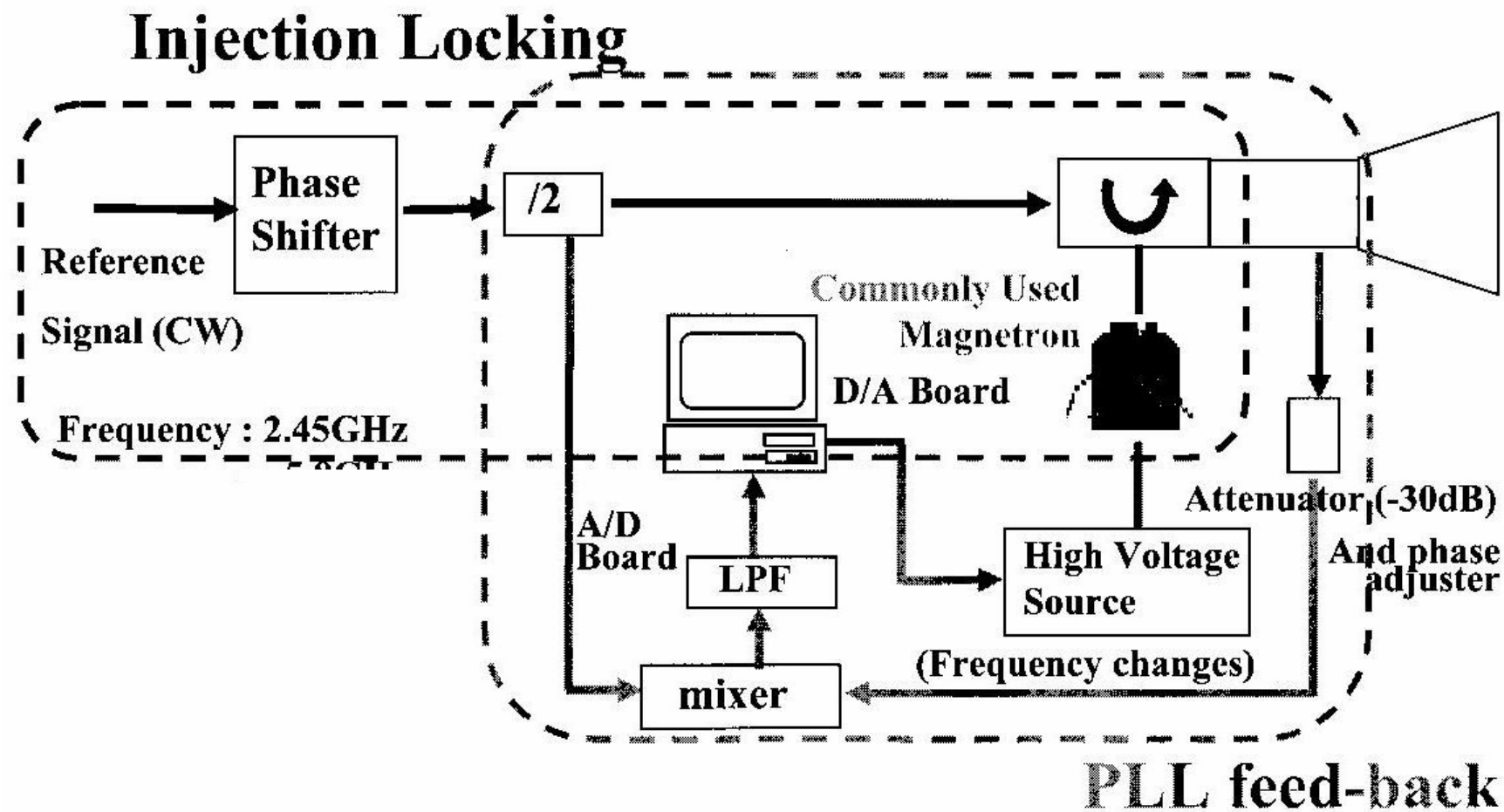
Phase Locking by PWM Method



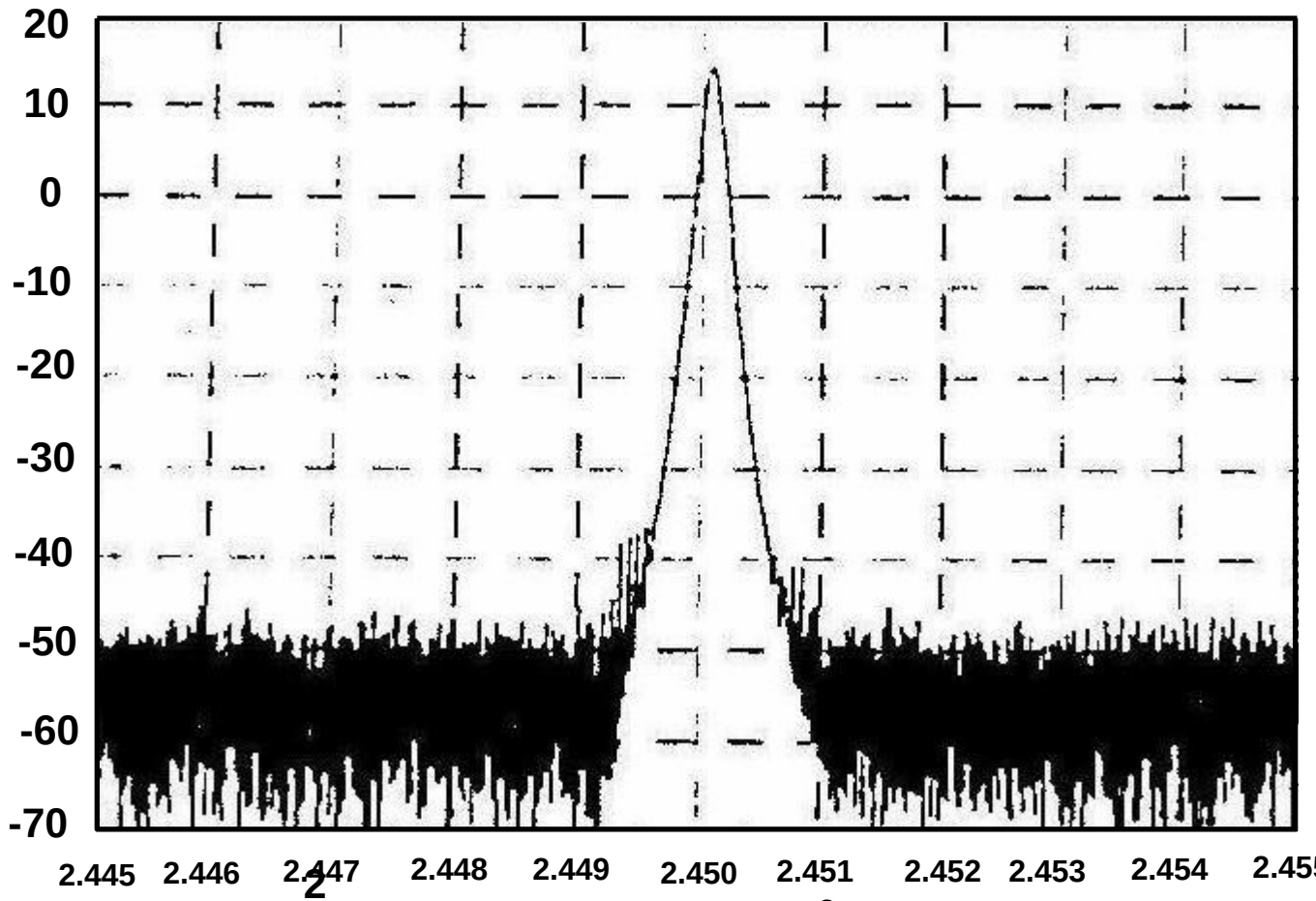
Phase Locking by VCCS Method



Work done by Kyoto University, Japan



Frequency spectrum (Locked)



Span: 10 MHz
RBW: 100 KHz
Pi/Po: -33dB
Centre Frequency: 2.45 GHz