SR2000 FREQUENCY MONITOR

THE FFT SEARCH FUNCTION IN DETAILS

FFT Search is a signal search using FFT (Fast Fourier Transform) technology.

The FFT search function first appeared with the SR2000 Frequency Monitor, therefore we will refer to the previous Search technology as “NORMAL Search”, as it is in use in our previous receivers like the AR8600.

HOW NORMAL SEARCH OPERATES

First we have to decide upon the frequency span and the step size to base our example on: [1]

Lowest frequency limit	83.0MHz
Highest frequency limit	93.0MHz
Frequency Span	10MHz（=93.0−83.0）
Frequency step	100kHz
Search Direction	Ascending

After setting the above search parameters, the following actions occur:

1. The lowest frequency limit 83.0MHz is set.
2. The SR2000 checks the presence of a signal.
   The receiver will stop on a signal if it detects one as set in the parameters. [2]
3. If the previous signal disappeared or the signal is not within fixed parameters, the search will continue at the previous frequency plus the frequency step.
4. The SR2000 checks the presence of a signal.
5. Step 3 & 4 are repeated until the checked frequency becomes the highest frequency limit set above.
6. Return to step 1 when the highest frequency limit has been reached.
   …

Normal Search speed calculations [3]

For instance the AR8600 searches 37 steps per second. On the other hand, the total number of channels to search is calculated as below:

$$\frac{93.0\text{MHz} - 83.0\text{MHz}}{0.1\text{MHz}} + 1 = 101 \text{ channels}$$

（100kHz = 0.1MHz）Dividing the number of channels to scan by the search rate gives the time necessary for a total search between the lowest and highest limit frequencies, providing no signal was present.

$$\frac{101}{37} = 2.72973 \text{ seconds}$$

The next example is based on a frequency step of 10kHz only, which is 10 times smaller than in the previous case.

$$\frac{93.0 - 83.0}{0.01} + 1 = 1{,}001 \text{ channels}$$

As there are roughly 10 times more channels to process, it will take 10 times more time to the AR8600 to cover the same range, therefore about 27 seconds.

As the search time is directly depending on the frequency range and frequency step, it is easily imaginable about how long it would take to make a full 25-3000MHz search with a 5kHz step.

How to speed-up the search?

With the Normal Search method, there is a limit at speed improvements, since even if the search rate would be 100 channels per second, it would only represent an improvement of 100/37=2.7 times. Although it looks good at first, it is only minimal in regards to the large band portions to search. The search method is the real problem.

This is where the SR2000 has a very different approach, with its:

THE FFT SEARCH FUNCTION

FFT is explained here in a simplified style, therefore please consult engineering and mathematics manuals for further details.

FFT stands for FAST FOURIER TRANSFORM, a mathematical analysis of non-periodic signals. It’s an equation to calculate the frequency, amplitude and phase of each sine wave needed to make up any given signal.

FFT SEARCH vs. NORMAL SEARCH

What is the difference between NORMAL SEARCH and Fast Fourier Transform SEARCH? What makes it really “Fast”?

Let’s take an example of +/- frequency span of 50kHz (total 100klHz) around 10.7MH.z. Signals are analyzed at a step size of 4kHz.

In the case of NORMAL SEARCH:

1. The lowest frequency limit is set at 10.2MHz（10.7 - 0.5）.
2. Signal presence is checked.
3. When a signal is detected, it’s frequency and signal strength is then recorded.
4. The search will continue at the previous frequency plus the step frequency, repeating steps 2 to 4, until the frequency reaches 11.2MHz（10.7 + 0.5）.

In the case of FFT SEARCH:

1. 10.7MHz is set as the center frequency.
2. The signals are processed by FFT.
3. FFT processed data output

That’s all! The receive frequency remains unchanged.

Processing speed comparison:

For Normal Search, let’s use the same example based on the AR8600, of which search rate is 37 channels per second.

$$\frac{11.2 - 10.2}{0.004} + 1 = 26$$

Therefore the time necessary to complete the search is 26 / 37 = 0.7 seconds.

For FFT Search, the SR2000 and its FFT have the power of sweeping a whole 10MHz span in only 0.85 seconds [4], therefore for only a small portion of 100kHz, it would take:

$$0.85 \times \frac{0.1}{10} = 0.0085 \text{ sec.} (= \frac{8.5}{1000} \text{ sec.})$$

In this case, FFT allows a search, which is 0.7 / 0.0085 = 82.35 times faster than Normal Search!

Now let's compare both technologies in an example where the entire range between 25 and 3000MHz would have to be searched with a step size of 100kHz.

Normal Search - Calculation of the number of channels to be scanned:

$$\frac{3000 - 25}{0.1} + 1 = 29{,}750 \text{ channels}$$

Therefore the time necessary is 29,750 / 37 = 804.05 sec. = 13.4 minutes.

FFT Search

$$0.85 \times \frac{3000 - 25}{10} = 252.88 \text{ sec} = 4.2 \text{ min.}$$

In this case the SR2000 and its FFT is 13.4 / 4.2 = 3.19 times faster than a Normal Search. It looks only as an OK result but this is because of the step frequency of 100kHz. In the case of a smaller 10kHz frequency step, the FFT shows its real power, as follows:

$$\frac{3000 - 25}{0.01} + 1 = 297{,}500 \text{ channels}$$

Compared to a 100kHz step size, 10kHz implies 10 times more channels, thus 10 times more time to complete the search. It would take 8040.5 seconds, or approx. 134 minutes with Normal Search to be completed. But as FFT Search is not step size dependant [5], it would take only 4.2 minutes, which is 31.9 times faster than Normal Search and this demonstrates the incredible power and speed of FFT SEARCH!

A full range (25MHz-3,000MHz) search which took more than 2 hours to complete is now possible in just 4.2 minutes thanks to FFT SEARCH!!

You might wonder why the SR2000 still features the Normal Search. As a matter of fact the ways of using Normal Search and FFT Search are quite different and therefore Normal Search can still be more suitable for certain application, as explained below:

NORMAL SEARCH allows the automatic audition of detected voice signals, as search progresses. But search is only "linear".

FFT SEARCH is principally about signal “detection”.

It’s point is to detect signals, determine their frequency & signal strength [6], and this in real time on the entire set frequency range, not in a linear order like for Normal Search. In addition, the detected frequencies are listed on the screen and you can tune the receiver to the frequency of your choice for listening, by simply moving a cursor.

There are also smaller technical particularities as follows:

- Very faint signal detection.

  Although the SR2000 RFU noise floor is at approx. –117db, FFT Search detects signals starting at –100dB. For this reason it is advised to use Normal Search for the detection of extremely week signals between these two values.

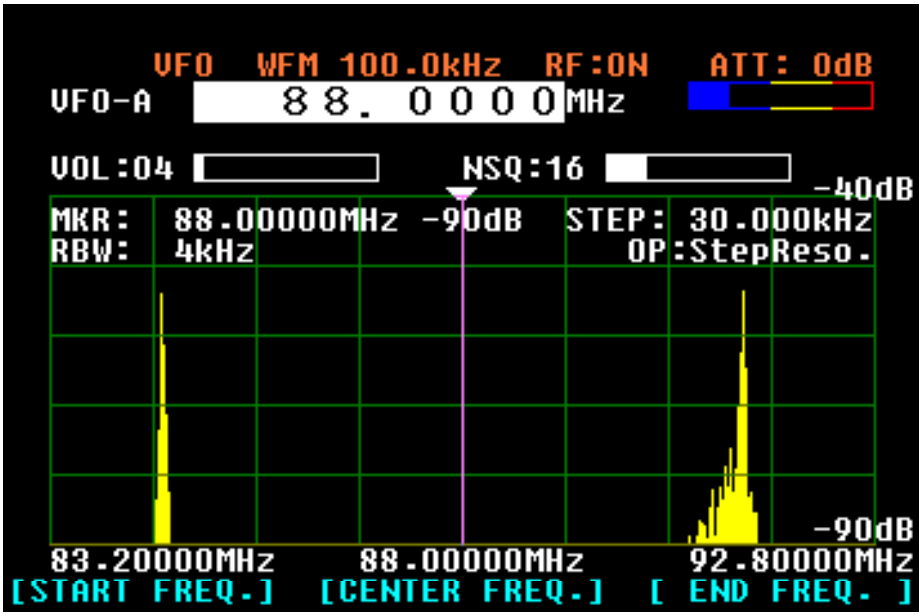
- Resolution bandwidth below 4kHz.

  The Resolution Bandwidth is fixed at 4kHz for FFT Search, therefore it is advisable to use Normal Search if you seek to detect more than one signal within the 4kHz bandwidth. [7]

FFT Search operation details

FFT Search on spectrum display

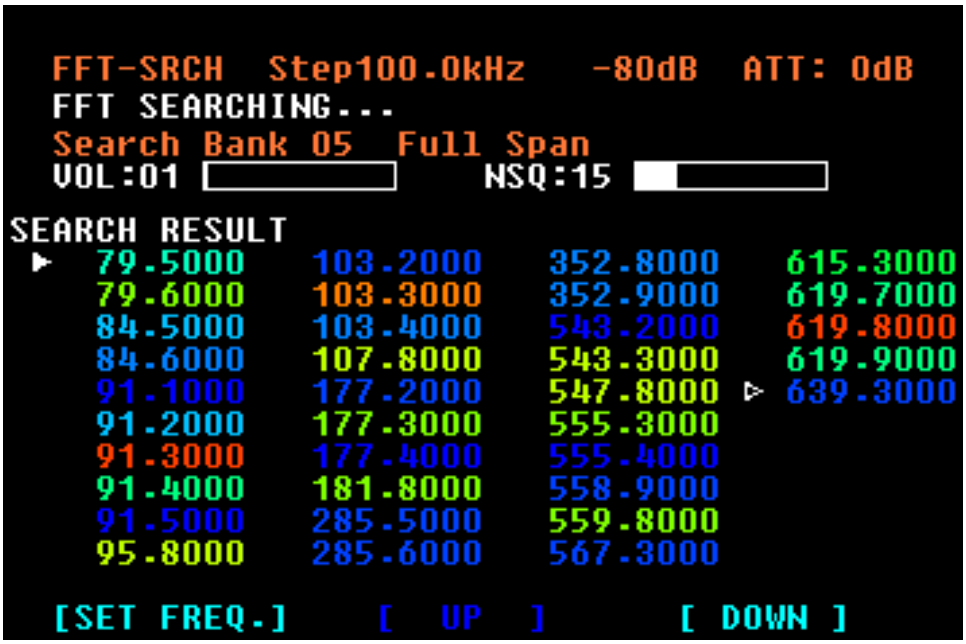
The following screen shot (1) shows the detection of two signals, both at –53dB.



Screen shot 1: VFO mode

FFT Search in numbers

With help of the dial operated marker, you could visually tune to any signal over 60dB and check the exact frequencies.



Screenshot 2: FFT SEARCH in action

SR2000 at work

The Frequency Monitor's job is for example to tell you all frequencies within a given bandwidth which represent a signal stronger than –60dB. The results of this FFT search are given either by a spectral visualization (see screen shot 1), or in a list of frequencies with color coded signal strength (see screen shot 2). In this case the data is also streamed through the serial port for PC analysis.

What if the frequency span to search exceeds 10MHz?

Although the maximum frequency span in VFO Mode is 10MHz、in FFT Search mode this range is only limited by the RFU's reception range (25-3,000MHz). The RFU unit's IF output is at 10 MHz., which sets the limits for the VFO frequency span. In FFT Search mode the SR2000 can achieve a full range 2975MHz search by shifting the RFU as described below:

First the RFU is set at 30MHz +/- 5MHz and this 10MHz section will be searched.

Then the RFU is set at 40MHz +/- 5MHz and this new 10MHz section will be searched

The same method is applied until the RFU reaches the upper frequency limit of 3,000MHz.

Footnotes:

[1] Various other secondary but necessary settings like receive mode and squelch are omitted here, to simplify the explanation.

[2] For the AR8600, as well as other AOR receivers, the time after which the search will resume, depends on the “Search Free” settings of the receiver.

[3] Calculation here are based on typical specifications as per manual, nevertheless in real use situations, results might vary depending on external factors.

[4] Although the spectrum display is indeed refreshed every 0.2 seconds, it takes more time for the RFU to switch frequencies. For those reasons it takes the SR2000 in reality 0.85 seconds for a 10MHz sweep.

[5] As it takes time for the SR2000 to send the results to the screen and through the serial port, the actual search speed might decrease depending on the number of frequencies found during the sweep.

[6] The signal strength value is output through the serial port to the PC.

[7] Although it is possible to set a resolution bandwidth of 1 or 2kHZ in FFT Search, the results are calculated by interpolation.