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Technical Note

Sampling and Scanning in the Griffin Series of Receivers from Willtek Communications

Introduction

The Willtek Griffin receiver is designed to form part of measurement systems to survey RF fields and investigate the characteristics of RF channels used in mobile communications systems. This paper describes how the Griffin receiver measures RF signal strength and dicusses the many issues with the measurements including the sampling and averaging processes. Accurate results are obtained with the Griffin when correctly set up. The settings are explained and their effect upon results is discussed. The Griffin has been designed to meet all of the RF field surveying needs of a mobile operator, from initial CW surveys through prediction model calibration to detailed problem investigation and network optimisation.

The receiver, controlled by a PC, operates in frequency scanning or memory cycling modes and has three methods of measuring the RF field. Griffin includes pulse counters allowing the RF to be sampled at precise distance or time intervals.

1. Mobile communication system testing

The Griffin is designed to measure two fundamental properties of an RF field from a transmitter: the RF field distribution over an area and the statistics of the multipath. It will also measure the occupancy of a set of communications channels.

1.1 Log-normal field variation

The RF field from a transmitter falls slowly with distance from the transmitter following a log-normal curve. This is the underlying RF field that is predicted from RF prediction tools. In practice the field does not follow the log-normal curve due to effects such as shadowing, clutter attenuation etc. This is why the field is measured to determine what it really is and hence how accurate is the prediction.

These measurements are distance-based and typically use the Lee[1] or Parsons[2] criterion to select appropriate sampling intervals in the range 0.3 to 0.8 lambda. To derive the actual RF field from the individual samples, from 40 to 85 readings are sent to the PC where they can be stored and averaged or the processing varied to derive the optimum measurement of the field.

The Griffin's fast tuning ability to change channel 1000 times per second allows surveying speeds of up to 100 kph on up to four channels.

[1] Estimate of Local Average Power of a Mobile Radio Signal, William C.Y. Lee, IEEE Trans. Veh. Tech. Vol VT-34, No. 1, Feb 1985.

[2] The Mobile Radio Propagation Channel, David Parsons, John Wiley & Sons 1992, ISBN 0 471 96415 8.

1.2 Multipath

Multipath due to reflections from various objects causes variations in the observed RF field. These variations tend to change rapidly with distance. They act as 'noise' on the measurement of the underlying log-normal field. Measurements of the multipath (short-term) fading are made to deter-mine the actual variations in RF field that would be observed by a receiver.

These measurements identify the statistical characteristics of the fast fading channel. The intervals between samples could be based on distance or time, leading to results such as 'histogram covering 100 m of road' or 'histogram covering 10 s'. Two measurement modes are available in the Griffin – histogram or level crossing rate. These modes re-quire the Griffin to remain tuned on the RF channel for the duration of the measurement.

The full histogram would be reported to the PC which calculates the statistics. Confidence and percentage measurements show the ratios of the numbers of samples above and below thresholds leading to results such as 'percentage of time above 47 dBμV' or 'percentage of distance above 30 dBμV'.

1.3 Channel occupancy

Channel occupancy measurements determine whether an RF channel is in use or not by setting an RF level as the threshold.

The Griffin is able to scan across 1000 channels per second and report the RF power in each one to the PC. Where more elaborate actions are wanted, such as changing mode to measure on a channel that exceeds a threshold, this can be done by control from the PC.

2. The major functional blocks of the Griffin

This section describes some of the key functional blocks of the Griffin receiver. The secondary blocks have been omitted for clarity.

2.1 Autoranging attenuators

The Griffin receiver has instant switching of its input attenuators and IF bandwidth. The receiver has a detector that operates over its whole input bandwidth to detect large off-channel signals.

▷ Function

There are two for the attenuators serve two functions:

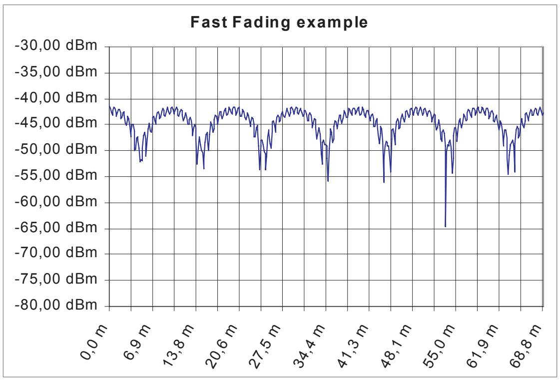
a) to avoid overloading the input circuits and

b) to match the dynamic range of the signal to the log amp, the detector of Griffin.

This means that it is necessary to look at both the peak power at the input of the receiver and the signal amplitude to decide on the correct attenuator setting to use. Where the limit is the signal input to the log amp, the minimum attenuator setting might vary from channel to channel. Where the limit is the input of the receiver, then it will be the same from channel to channel.

▷ Per frequency autoranging

The decision to autorange is made by the microprocessor whenever the frequency is changed. The microprocessor will remember the last measurement on a frequency and, when resetting to that frequency, set the appropriate attenuator. This is most useful if there is some correlation between subsequent measurements on a frequency. When setting the attenuator the microprocessor will pay regard to both input level detector and measured values.



▷ Summary

The effective dynamic range when changing frequency is 110 dB, as long as the input power is limited and there is some correlation between measurements. This is acceptable since most measurements will be done where the underlying log-normal field does not vary significantly during the data collection period.

2.2 RF section

This is a conventional dual-conversion receiver with a broad-band power measurement facility operating over the whole RF bandwidth. This is used to measure the total RF power in order to detect the onset of overload to the input circuits.

▷ IF filter

The IF filters in the Griffin have been chosen to optimise measurements made with CW transmitters (15 kHz) or with GSM modulated transmitters (200kHz). The 15 kHz filter gives an 11 dB improvement in signal-to-noise ratio when compared to the 200 kHz filter.

▷ Logarithmic detector

The RF signal is detected by a wide dynamic range logarithmic amplifier. The response of the log amp is very fast so any variations in the amplitude of the RF from the IF filters is present in its output. The GMSK modulation used by GSM is a constant amplitude modulation, however, after band limiting this will have some variations in amplitude. These must be filtered out to avoid errors in the measured signal level.

▷ Noise filter

The receiver bandwidth is limited by a 12 kHz filter following the logarithmic amplifier. (The reason for the choice of a 12 kHz bandwidth is explained later in this document).

The maximum frequency of the fading spectrum is twice the doppler shift . At 40 m/s speed and frequecy 2 GHz this is 535 Hz. Clearly there is room for noise to be present in the band from about 550 Hz to 12 kHz. The Griffin contains a set of noise filters that can be switched into circuit following the logarithmic amplifier to reduce the bandwidth. The available bandwidths are 150, 300, 600, 1200, 2400, 4800 and 9600 Hz.

The disadvantage of using one of these filters is that they reduce the number of RF channels that can be observed per second. This is caused by the time the filter takes to settle to its final output level. When the receiver tunes to a new frequency the filter must be given long enough to settle to its final output. The narrow the filter, the longer it takes to settle. A table of settling times is given in section 6.

▷ Pulse counters

The pulse counters determine the sampling instants in the receiver. There are three types of counters in the Griffin. These are:

- Pulse counter
- Predivider
- Sampling counters

These are described below.

▷ Accumulators

There are two accumulators, one for the internal clock and one for the external pulses input. These are both 32 bits long and count the 'raw' pulses. They are reported to the PC along with the results data and are intended to allow precise 'positioning' of the data either in time or distance. There are three options for how often the accumulator is reported to the PC for use in different situations.

▷ Predivider

There are two predividers, one for the internal clock and one for the external pulses input. They can be individually set to divide by any number from 1 to 65536. The predividers set the resolution of the sampling counters. So, for example in precision distance measurements, if a wheel encoder gave 13 pulses in 10 cm, setting the predivider to 13 would set the resolution to 10 cm. The sampling counters would work in units of 10 cm and hence the shortest interval between measurements would be 10 cm.

▷ Sampling counters

There are five sampling counters in the Griffin. These can be connected together and to the predividers in various ways to meet the needs for different patterns of measurements. Each sampling counter can be set to count from 1 to 65536.

When any of the counters reaches 0 the Griffin will take some action. The actions include:

- Trigger another counter
- Take a sample
- Go on to next frequency

By setting suitable combinations of the five counters, complex sampling patterns can be created. These are explained in more detail in section 7.

3. Types of measurements

There are five Measurement processes available in the Griffin receiver as follows: Histogram, Maximum, Minimum, Mean, and Level-Crossing Rate. The Maximum, Minimum and Mean of a number of readings can be measured at the same time. The Mean of one reading is used as a simple single measurement.

Whether Scanning or Memory Cycling, the measurement process is the same on every frequency. The process takes from 1 to 216 readings of the RF signal strength and derives the required measurement from the readings. Since the clock can be derived from either time or distance, the measurement readings can be spaced equally in time or distance.

The Measurement process can be repeated up to 216 times before moving on to the next frequency. Thus from one to four billion readings can be processed on a frequency.

3.1 Histogram

The Griffin gathers histograms consisting of counts of the numbers of observations of each dB value. So, for example, there is a count for 56 dBµV, another for 57 dBµV etc. for the whole 80 dB instantaneous dynamic range of the receiver. These counts will be stored in the receiver and reported to the PC when the histogram is complete. There is sufficient storage in the Griffin to hold two complete histograms so that whilst one is being filled the other can be reported to the PC resulting in no gap during the sampling.

A maximum of 65536 readings can be gathered to produce one Histogram. For illustration, at the maximum sampling rate of 100 ksps this would take 0.65 seconds. Multiple histograms can be summed in the PC to give the effect of larger histograms.

The Griffin cannot autorange whilst gathering the readings for a histogram but can autorange before the next histogram (on the same or another frequency). Any values outside the range are accumulated into over and underrange bins and reported to the PC.

3.2 Maximum, minimum, mean

This measurement extracts the Maximum, Minimum and Mean of a series of readings on a single frequency (abbreviated to MmM). This can be viewed as a peak detector reporting maximum or minimum peaks or as a averaging filter to smooth the signal. The Griffin can report any combination of these three measurements to the PC simultaneously.

The results of one process are held in temporary storage inside the Griffin so that the next process can start immediately whilst the results are being sent to the PC.

The Griffin does not autorange whilst gathering the readings for a MmM but can autorange before the next MmM (on the same or another frequency).

▷ Mean of the log

The averaging is done on the log of the signal rather than on its linear magnitude. This introduces errors if the signal varies greatly in amplitude. Reporting the maximum and minimum values allows the PC to assess the validity of the mean.

Prof. Parsons gives equations relating mean of linear to mean of log record for a Rayleigh signal.

▷ Single Reading

The same value of a single reading is achieved by asking the Griffin to measure the Mean of one reading.

▷ Mean or mode from histogram

An alternative to measuring the Mean is to gather a histogram and to calculate the true mean or mode etc. from it. Since the number of times any particular level was observed is known, the mean can be accurately calculated in the PC. This technique would be inefficient for small numbers of readings.

▷ Level-crossing rate

The level-crossing rate is the number of times the signal crosses a specified level in the positive-going direction per second. This is derived in the Griffin over a set number of readings (up to 65536).

4. Correcting the readings

The Griffin achieves its accuracy by applying corrections to the raw measurements. The corrections needed by each receiver are measured during the manufacturing process and stored within it. Since all electronic circuits vary with age, it is important the corrections are renewed annually by a Willtek-approved calibration process if the receiver is to meet its accuracy specifications.

Logarithmic amplifier accuracy

The logarithmic amplifier in the Griffin is a high-specification part offering very good conformance to a logarithmic law, however it is not good enough to meet the exacting Griffin specification. Each amplifier is measured over its operating range to derive a table relating the input level to the output voltage. This table is then used to convert each voltage reading to an RF power.

▷ Gain flatness of the receiver

The front end of the receiver is not perfectly flat with frequency. A table of gain values at various frequencies allows the receiver to correct all readings on any frequency.

▷ Gain changes with configuration

The apparent gain of the receiver will vary slightly depending on its internal configuration. For example there will be a gain difference between the 200 kHz and the 15 kHz filters. The precise gain of every configuration is measured and stored in the receiver and used to correct the readings.

▷ Gain changes with temperature

All RF circuits will vary to some extent with temperature. The changes include gain, noise figure and linearity, all of which will have an impact on the performance of the receiver. The Griffin has been carefully designed to minimise the impact of these changes on the measuring ability of the receiver. The most important parameter affecting the measurement accuracy of the receiver is its gain. It is not possible to make the gain absolutely stable with temperature so, instead, a precision reference source is included. This is measured at intervals to calculate the actual gain of the receiver and this figure is used when calculating the input power level.

5. Controlling the sampling instants

The Griffin's pulse counters can be set to specify the pattern of measurements to be made. The pulses that input to these counters can come from outside the receiver, for example from a wheel encoder, or from an internal 100 kHz clock giving a time resolution of 10 µs. The internal clock is derived from a crystal oscillator hence is highly accurate.

The Griffin has a sample pulse output that can be connected to other Griffin receivers so that the sampling of all of them is synchronised.

Distance measurement

The pulse will come from a pulse encoder on a wheel and so will measure the distance travelled. To keep this distance accurate a counter is maintained continuously, independent of any sampling.

The pulse count is returned with each block of measured data or on demand.

The 16-bit divider in the Griffin, with inputs of 200 pulses per metre, will allow a maximum gap of 327 metres between samples.

▷ Input

The input will be pulses from various devices. These might vary in the 'cleanliness' of their pulses, so some clean-up will be needed. The input is TTL levels or similar.

▷ Counter

The pulses tend to be at a rate of up to 200 per wheel revolution. For a wheel of 1 m circumference this is 2 pulses per cm.

At 90 mph (40 m/s) this results in 8000 pulses per second.

At this speed the 32-bit counter in the Griffin would last 500,000 seconds or 6 days before rollingover to zero.

▷ Calibration

To determine the number of pulses per km of travel we will need calibration facilities. These will be:

- Clear counter
- Start counting pulses
- Stop counting pulses
- Read pulse counter

No measurements can be made whilst calibrating the pulse counter.

▷ Time-based measurement

The sampling clock is derived from an oscillator running at 100 kHz, giving a time resolution of 10 µs. The clock feeds a programmable predivider to set the time resolution of the other counters. The 16-bit divider will allow a time resolution from 10 µs to 650 ms. The time resolution is the minimum separation between samples and hence sets the fastest available sampling rate.

Setting the time resolution can be a compromise between sampling rate and the longest interval required. Since the counters are all 16-bit the longest interval is 65536 times the time resolution. Thus it is not possible to set a time resolution of 10 µs and ask for an interval of 12 s at the same time.

It can be easier to think of setting the time resolution than a sampling rate. The following table lists the five shortest time resolutions and hence fastest sampling rates that can be set.

Predivider	Time Resolution	Sampling Rate
1	10 µs	100 ksps
2	20 µs	50 ksps
3	30 µs	33.3 ksps
4	40 µs	25 ksps
5	50 µs	20 ksps

Clearly there is large granularity in setting the sampling rate. However this is rarely a problem in practice since the requirement is usually to set the sampling time rather than any particular rate.

6. Issues related to sampling

The Griffin does not measure the RF field continuously but rather it samples the field at defined intervals. The correct choice of the sampling interval depends on the kind of information that is needed. This issue is related to the Lee criterion which specifies the best sampling interval to measure the log-normal RF field.

6.1 Minimum sampling rate

The Griffin samples the RF field at defined intervals, and these intervals can be spaced in time or in distance. Whenever sampling a signal it is essential that the samples are close enough to detect any change in the signal. If the samples are spaced too far apart changes in the signal can be missed. If the samples are closer together no harm will be done, but they will not yield any more information. The only disadvantage of over-sampling in the Griffin is that the additional processing will reduce the life of the battery slightly. The choice of sample interval (or equivalently sample rate) will differ between samples spaced in time or in distance.

▷ Samples spaced in time

Nyquist calculated the theoretical minimum samp-ling rate for a signal that varies with time as "at least two samples per second for each Hertz of bandwidth". This limit is know as the Nyquist limit and, in practical systems, four to ten times this rate is needed. An example of using the Griffin with samples spaced in time is when measuring the statistics of a channel. In this case it is advisable to ensure that the signal is sampled at an adequate rate or very short-term changes would be missed.

▷ Samples spaced in distance

The situation with samples spaced in distance is a little more complex and depends on the type of measurement being done. The two cases to consider are a) measuring the fade statistics as a function of distance and b) measuring the log-normal RF field.

a) When measuring the fade statistics as a function of distance, the criterion is to take sufficient samples per wavelength to ensure that sharp fades are not missed.

b) When measuring the log-normal RF field a different criterion such as Lee's one is used.
The rate of sampling is far too low to measure the multipath fading, indeed this appears as noise on the measurement which is reduced by averaging the samples.

The sampling rate is fast enough to measure the changes in the log-nomal RF field.

In both cases there might be noise from various sources present on the signal. This noise can be reduced by a filter following the log amp detector and will have the effect of improving the signal-to-noise ratio of the measurement.

▹ Time-based sampling

The bandwidth prior to the log amp detector is set by the choice of 200 kHz or 15 kHz IF filter. This sets a maximum rate at which the envelope of the RF can vary, however, in practice it will vary much more slowly. The bandwidth that the Griffin samples, is set by the filter following the log amp detector. This has a maximum bandwidth of 12 kHz but can be reduced by the noise reduction filter to suit different situations.

With the noise filter switched out, the bandwidth in the Griffin is 12 kHz; sampling this at 50 ksps would be adequate to ensure accurate sampling over the whole of this bandwidth. In many cases sampling at a lower rate would be perfectly adequate if the user knows that there are no signals present in the detected RF at higher frequencies. So, for example, if no signals are present over 1.2 kHz a sampling rate of 10 kHz would be fine. In practice it is hard to be sure that there are no higher-frequency signals and there will always be high-frequency noise. The role of the noise filters in the Griffin is to remove any higher-frequency signals and noise. They allow reduced sampling rates and improve the signal-to-noise ratio in the wanted bandwidth.

The disadvantage of the noise filter is that the settling time of the filter reduces the number of channels that can be measured per second.

The following table shows the minimum sampling rates that are imposed in Willtek Hindsite software driving the Griffin. These are not imposed inside the Griffin, so users can choose different rates if they prefer. The rates are set at 10 times the 3 dB bandwidth of the noise filter which, with the Bessel filters in the Griffin, will give at least 40 dB attenuation of noise above the Nyquist frequency.

Noise Filter Bandwidth	Minimum Sampling Rate
Out	100 kHz
9.6 kHz	100 kHz
4.8 kHz	50 kHz
2.4 kHz	25 kHz
1.2 kHz	12 kHz
600 Hz	6.0 kHz
300 Hz	3.0 kHz
150 Hz	1.5 kHz

The choice of the most suitable filter bandwidth in any particular application is a trade-off between speed and accuracy of measurement. In general the narrowest filter should be used that is wider than the expected fading spectrum and still allows the RF channels to be scanned.

As an example, the maximum bandwidth of the fading spectrum on a 2 GHz carrier with a vehicle travelling at 40 m/s is about 650 Hz. This could be sampled at 12 kHz through a 1.2 kHz noise reduction filter.

▹ Related issues

Measuring the fade statistics on two channels at once
To measure the fade statistics of two channels at once the Griffin would have to tune between the two channels and take a sample on each of them at a rate greater than the Nyquist rate. The Griffin is able to do this kind of measurement with certain limitations on the frequency and speed of travel. When tuning between two channels the Griffin can sample each at 500 sps. Hence, if the fade bandwidth on each channel is limited to about 100 Hz, they would both be sampled at about five times the maximum frequency. It would not be possible to use a noise filter to improve the SNR as it would reduce the sampling rate below 1000 per second. An example of a possible measurement would be on two 1 GHz carriers whilst travelling at 13 metres per second (30 mph).

GSM power variation

The GSM signal varies in magnitude every time slot of 577 µs duration. When scanning or cycling around channels there is no way of ensuring that the same slot is measured each time. For example, cycling between two GSM carriers would result in about two measurements per frame of eight time slots (4.62 ms).

A histogram could be used on a single channel to observe time slot to time slot variations.

Noise filter to reduce variations in measured signal level due to the modulation.

▹ Distance-based sampling

Distance-based sampling means sampling every X wavelengths; this is what we do when using the Lee criterion.

Now the RF field strength is known to change slowly compared to the rate at which we sample it, since samples spaced closer in distance become correlated.

In other words the sampling criterion is calculated on the expected variation with distance rather than variation with time. One sample per wavelength is the correct rate, neither under nor over-sampled.

There might, however, be noise on the signal being sampled causing it to show faster variations. The noise would be time-based, hence present even if the vehicle was stationary. The 'correct' bandwidth to filter the noise depends on the SNR and the speed of travel. An ideal approach would be to move to the new position and pause whilst the signal is integrated to achieve the desired SNR.

In practice we wish to drive as fast as possible. With a 100 ksps sampling rate we could use a 12 kHz lowpass filter to measure the average signal over a period of about 60 µs (It is similar to the Video filter in a spectrum analyser). At 100 km/h, a sampling period of 60 µs is a distance of 2 mm or 1.2% of the wavelength at 2 GHz (50 µs leads to 1%). If we were to use a 600 Hz filter (matched to the fade spectrum) we would sample over a distance of 50 mm or 0.3 lambda.

Where we wish to drive more slowly, scan fewer channels or work at longer wavelengths, then averaging could be used to smooth the measurements. For example, at 1 GHz and 50 km/h we could average four readings.

6.2 Sampling control in the Griffin

There are four factors that can be adjusted in the Griffin to control how the RF field is sampled. These are:

- IF bandwidth
- Noise filter bandwidth
- Measurement type
- Sampling pattern

The settings of these must be chosen to match the type measurement needed.

▷ IF bandwidth

The IF bandwidth must be set to suit the transmitter being measured. The two options are 200 kHz for a transmitter with GSM modulation and 15 kHz for a CW transmitter. The choice of a 15 kHz IF filter reduces the time the RF power measurement takes to settle and hence reduces the number of channels that can be measured per second.

▷ Noise filter bandwidth

The noise filter should be set as narrow as possible to give the best signal-to-noise ratio for the measurement. If the bandwidth is set too narrow then the filter cannot settle quickly enough and the number of channels that can be measured per second is reduced. The following table gives estimated values.

Filter Bandwidth	Acquisition Time	Total AT200ksec	Freqs 200kAT
12 kHz	60 µs	1.0	1000
9.6 kHz	75 µs	1.035	960
4.8 kHz	150 µs	1.10	900
2.4 kHz	300 µs	1.26	790
1.2 kHz	600 µs	1.56	635
600 Hz	1.25 ms	2.21	445
300 Hz	2.5 ms	3.5	285
150 Hz	5 ms	6	165

The number of frequencies per second is calculated based on 800 µs to change frequency and then the total acquisition time. The total acquisition time is the sum of the acquisition times for the IF, PDF and noise filters.

▷ Measurement type

TCR measurements are time-based by definition. It is necessary to sample at over the Nyquist rate for the expected fading bandwidth or crossings could be missed.

Histogram measurements of the statistics of the channel (multipath) could be time or distance-based depending on how the user wishes to express the resulting statistics. These need to be sampled at an adequate rate or some fades be missed leading to incorrect statistics.

Maximum and Minimum measurements will not detect the correct values if the samples are too widely spaced as the peaks or troughs could be missed.

Mean measurements over a lot of samples on noise-like signals will probably give reasonably good results even if the samples are widely spaced. Whilst some peaks and troughs might be missed a representative number of them will be sampled leading to small errors.

The Mean can be used as an alternative to a noise filter to improve the signal-to-noise ratio of a measurement.

▷ Sampling pattern

Clearly the sampling pattern determines how often a channel is sampled. The most frequent patterns are ones matching the Lee criterion on several channels or fast sampling on a single channel to measure its fading statistics.

The Griffin enables complex measurement patterns to be implemented with ease. For example, cycling round four channels taking a 50 ms histogram on each.

If this pattern was used whilst driving along a route the result would be comparative estimates of the fade statistics for the channels along the route. In this example the fade statistics themselves are being sampled every 200 ms. This could result in inaccurate statistics which is why they are only estimates.

7. Operating sequence

The Griffin has two basic operating modes: Memory cycling or Scanning. In either of these modes the sequence of processes that the receiver goes through on each frequency is the same. In outline the sequence is:

Set the frequency, bandwidth etc.

Wait until the measurement is triggered

Do the measurement (or measurements)

This sequence is repeated for each frequency.

Changing Frequency	Waiting for Trigger	Measurement
1 ms minimum	Wait based on time or distance (pulse count) or no wait at all (Trigger counter is restarted immediately on completion)	MmM (repeated) or Histogram (repeated) or Level-Crossing Rate (repeated)

The new frequency is set immediately upon completion of the Measurement period.

The Maximum/Minimum/Mean, Histogram or LCR might be repeated up to 65536 times before changing to the next frequency.

7.1 Memory cycling mode

Memory Cycling mode is intended for use when a limited number of predefined RF channels need to be measured. These will often be measured at specified distance intervals, but the Griffin can equally well measure at time intervals.

▹ Operation

In Memory Cycling mode the receiver can be programmed with entirely separate frequency, IF bandwidth, and attenuator setting (or autorange) for each of the 150 available memories.

The receiver can make measurements using the parameters in any single memory or to cycle round all of the programmed memories in sequence. At each frequency the receiver will dwell to do one of the measurements. The maximum number of channels that can be measured per second will depend on the measurement process chosen. For a single sample the rate will be 1000 per second.

▹ Processing in the PC

Averaging over N samples (Lee) or Histogram gathering can be done in the PC software for all 150 memories at the same time.

▹ Single frequency mode

Measurements on a single frequency mode are made by using Memory Cycling mode with only one memory.

7.2 Scanning mode

Scanning mode is intended for use when a set of equally-spaced RF channels need to be measured. Scanning mode is aimed primarily at stationary spectrum surveys or monitoring but can be used in other ways.

▹ Processing in the PC

Averaging or Histogram gathering could be done by software in the PC for all scanned channels at the same time in the PC (could be up to 12000 channels!).

▹ Sampling patterns

The flexible counters in the Griffin allow complex measurement patterns to be specified. The three most common patterns are:

- One Scan or Cycle then stop
- Scan or Cycle continuously repeating
- Scan or Cycle self-starting every X ms or Y meters

An alternative way of visualising the third pattern (grouped measurements) is as one Scan or Cycle followed by a pause. In all three patterns the gap between each reading and between each frequency is the same.

▹ Pattern for continuously repeating measurements

Evenly spaced measurements will be made every N pulses, where, if the pulses are derived from the clock the measurements would be made every X ms or, if they are derived from the distance input the measurements would be made every Y metres. So the Pattern will be: F0, F1, F2, F0, F1, F2 etc., with N pulses gap between the start points of each measurement.

An algorithm that explains the pattern is as follows:

Command from PC to start

Set first frequency

Start trigger counter

REPEAT

REPEAT

REPEAT

Do a measurement over M samples on frequency 'F'

LOOP N times

Change frequency

WAIT for trigger

Restart trigger counter

LOOP until all frequencies done

Report a set of results to the controller

LOOP until commanded to stop

The reporting might be done after each frequency or at the end of the set.

The wait for trigger could be on distance or on time. Thus can do a sequence every X ms or Y m. In both cases the 1 ms time to retune the receiver will be timed precisely.

Should the trigger arrive before the 1 ms has finished, then an overrun has occurred and this would be flagged to the PC.

▷ Pattern for grouped measurements

The pattern for grouped measurements is to do the measurements on all of the frequencies and then to pause before repeating the measurements. This pattern would be used, for example, to take closely-spaced measurements on four frequencies every 2 metres. The gap between measurements and the pause are set as numbers of pulses. These can be derived from the clock or from the distance input.

The Pattern will be: F0, F1, F2, pause, F0, F1, F2, pause etc.

An algorithm that explains the Pattern is as follows:

Command from PC to start

Set first frequency

Start group counter

REPEAT

Start trigger counter

REPEAT

REPEAT

Do a measurement over M samples on frequency 'F'

LOOP N times

Change frequency

WAIT for trigger

Restart trigger counter

LOOP until all frequencies done

Set first frequency

WAIT for group trigger counter

Restart group counter

LOOP until commanded to stop

The group counter could be on distance or on time, but it will always be the same as the trigger counter. Thus can do a sequence every X ms or Y m. In both cases the 1 ms time to retune the receiver will be timed.

Should the trigger arrive before the 1 ms has finished then an overrun has occurred.

▷ Mixed sampling

Mixed sampling means where the sampling instants are controlled by a time and a distance criterion. In this mode some of the counters in the Griffin will be counting time pulses and others distance pulses. This mode would be used to do a measurement such as 'Mean of 1000 readings taken every 2 m travelled.' In this application the mean is being used to improve the signal-to-noise ratio and the 1000 readings would be taken as fast as possible (10 µs spacing). The readings will be correlated but that is intentional since the meaning of the measurement is to take an average to represent the true value at that distance. Note that to make this valid, the total sampling period should be short-compared to the speed of travel.

Within the Griffin the measurement process is always over 'N' samples and hence over time or distance. The pulse source for the trigger counter is independent to allow mixtures between triggering and measurements. The counter for groups of measurements would be the same as for triggering.

This table shows the combinations of Trigger source and Measurement counters.

	Measurement Source	
	Time	Distance
Trigger		
Time	"Every 2 s gather for 0.1 s at 100 ksps"	"Every 3 s gather for 3 m at 15 cm" Fails if going too slowly
Distance	"Every 23 m gather for 10 ms at 100 ksps". Readings spread in space if going too fast	"Every 45 m gather for 2 m at 20 cm"

The mixed modes can fail to work correctly if the receiver is travelling either too fast or too slowly. The receiver attempts to detect these situations and to flag the measurement results as invalid.

▷ Alternative triggers

Instead of triggering measurements from the counters, the receiver can be triggered to measure by a command from the PC or by an input pulse. This allows multiple receivers to be synchronised to make simultaneous measurements on more than one RF channel.

▷ Data reporting options

To support these measurement patterns the Griffin has options to control how the measurement results are reported to the PC. Thus, for example, with several seconds between measurements they would be reported individually but at a fast rate of measurement they would be reported in groups.

There are similar options for how often the distance/time accumulator is reported.

8. Control and results data link

The control commands and results data can be communicated to the Griffin over an RS-232 data link.

8.1 Data format

The format of the data stream is the same whether using RS-232. There are various options available to fine-tune the volume of data that is reported to the PC. These are of most use with RS-232 to match the volume of data to the capacity of the RS-232, but can also be used to reduce the volume of data to be stored to disk inside the PC. The results can be reported in ASCII or in binary formats.

8.2 Interleaving replies

It is possible to interleave short messages to the PC with data. For example the receiver might be doing a long repetitive sequence and the PC might send a query on battery state. The reply will be fitted into the data stream between blocks of results data.

8.3 RS-232 Data link

▷ Baud Rate

See product specification for available rates.

▷ Buffering

Averaging or Histogram gathering could be done by software in the PC for all scanned channels at the same time in the PC (could be up to 12000 channels!).

8.4 Speed table

This refers to the speed of the vehicle. The Channels column is the number of RF channels that can be sampled at 2 GHz with one sample per wavelength (This is close to the Lee criterion). The obverse of this is that any less number of channels would be over-sampled.

Lee sampling at 2 GHz

m/s	km/h	miles/h	Channels
10	36	22	15
20	72	45	7
30	108	67	5
40	144	90	3

At 2 GHz the wavelength is 150 mm. We can sample 4 channels in 4 ms which equates to 111 mm at 100 km/hr.

Note that other pundits disagree with Lee.
For example, sampling at 80 per 40 lambda halves these channel numbers.

9. Examples of how these facilities might be used

This section of this paper explores how the facilities designed into the Griffin receiver might be used to make different measurements.

9.1 Field survey on three channels

Connect a wheel transducer to the receiver. Use Memory Cycling mode with three memories doing a single measurement on each frequency. Choose grouped measurements with a distance of 0.8 lambda between each group and 0 spacing between memories. The PC must average groups of 40 readings to calculate the underlying field.

9.2 Testing availability

Single RF channel. Use continuously repeating mode. Measure histograms and analyse in the PC for percentage above 47 dBµV. Set sampling interval of 0.1 lambda.

9.3 Perceived availability

As above but set sampling at 10 µs. Now get more samples on slow roads, fewer on fast roads. Reflects perception of user.

Could be useful for testing Rail systems since stops in stations are regular in time and this would show true % of time the system is available to the driver.

9.4 Measuring channel characteristics

Single RF channel. Use sets continuously repeating mode. Request histogram. Set sampling interval of 0.1 lambda or time. Analyse the histograms in the PC to derive the statistics over any section of the route.

9.5 Channel occupancy

Scan channels detecting the level over 1 ms. If a signal is detected then measure average level for 10 ms (to average out modulation) and report time and level. This needs active control from the PC to program which channels to measure.

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