GSM/EDGE Output RF Spectrum on the V93000

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Introduction

A key transmitter measurement for GSM and EDGE is the Output RF Spectrum, or ORFS. The basis of this measurement is very similar to that of ACPR (Adjacent Channel Power Ratio), but it differs in that the ORFS measurement applies a 5-Pole Synchronously Tuned filter (5PSTF) to the time domain signal. This is to smooth the response resulting from the pulsed nature of the signal, because the GSM/EDGE system uses time domain multiple access (TDMA) and therefore the transmit circuitry (power amp, etc.) must be switched on and off [1].

Since GSM and EDGE are pulsed signals, the PA must ramp up from standby state to full output power in a very short period of time (and then ramp down in the same time). This causes the PA to produce transmitted power outside the operational bandwidth of the system, commonly referred to as output RF spectrum. More specifically, this is termed “Switching” ORFS. Within the context of this paper, this will be referred to as SORFS.

When GMSK (GSM) or 8-PSK (EDGE) modulation is added to a pulsed system this contributes further spectral content. Within this context, this will be termed “Modulated ORFS,” or MORFS. Non-linearity in the PA causes additional spectral re-growth on this modulated signal in a similar manner as for WCDMA signals. Excessive spectral re-growth causes interference to other users operating in different frequency bands and can distort the transmitted signal and increase a device’s bit error rate [1]. Wideband noise will also contribute to signal degradation along with the phase noise of the VCO.

The ORFS measurements can be thought of as a form of adjacent channel power ratio (ACPR) and, along with a phase error measurement (GSM) or EVM (EDGE), can reveal numerous faults in the transmit chain, for example, faults in the I/Q baseband generator, filters and modulator [2].

ORFS Filtering (5-Pole Synchronously Tuned Filter)

The 5PSTF is used in the ORFS measurement for the purpose of smoothing out the pulsed response of the GSM and EDGE signals. This filter is applied in the time domain, much like that applied in a spectrum analyzer’s Video Bandwidth filtering algorithm.

This 5PSTF is 30KHz wide for measuring an offset of less than 1.8MHz and it is switched to 100KHz wide for the 1.8MHz offset. This filter is applied by frequency shifting the incoming signal to the desired offset to measure, then passing this frequency shifted waveform through the filter. This process is repeated until all the desired offsets are measured.

One of the inherent advantages of measuring ORFS instead of ACPR in a GSM/EDGE signal, even though both measurements are similar, is that, since ORFS is implemented in the time domain, no FFTs are needed to be taken in order to calculate the power at a specific offset, making this a faster way to implement this measurement.

Understanding the GSM/EDGE Burst

Figure 1 shows a time domain waveform of a GSM/EDGE burst, offset from the carrier, after being passed through the 5PSTF 30 kHz filter. The section defined by the video average level (60-90% of the useful portion of the burst) is what is analyzed for the MORFS measurement. This is implemented by internally gating the measurement. This gating is performed by a simple process:

1. Synchronize to a mid-amble.
2. Once the demodulator knows at which sample the synchronization occurs it knows where to start and stop the MORFS measurement.
3. The MORFS measurement is measured in two halves, one half on the front part of the packet while the second half on the back side of the packet.

The max hold level per offset is used for making the SORFS measurement, whereby the envelope formed by the switching transients is analyzed. The peak is held for the full length of the packet and the peak offset power is returned. This peak will typically happen at the transients at the point where the device is turned on and off due to ringing.

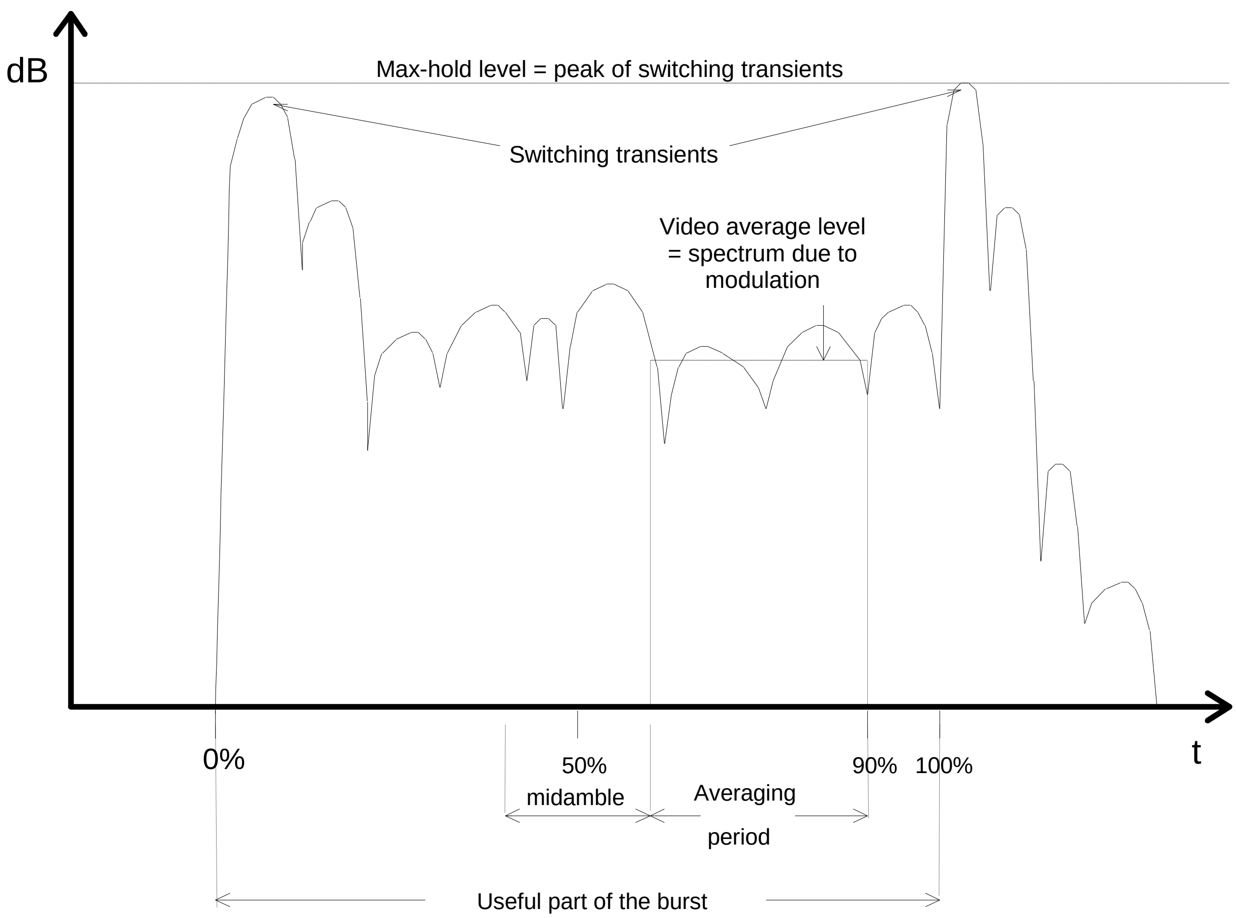

Figure 1 Time domain waveform of a GSM/EDGE burst, offset from the carrier, after being passed through the 5PSTF 30 kHz filter [2].

Typical ORFS Measurement Parameters

Devices designed for transmitting GSM/EDGE RF signals must pass both MORFS and SORFS. Measurement parameters and specifications for these are shown in Table 1, using GSM900as an example [1] [2].

For the MORFS measurements, power is measured at the specified offset with the stated resolution bandwidth (RBW) relative to the power in a 30 kHz channel centered at the carrier. It should be noted that the 400 kHz specification is usually the most difficult to meet, hence when 8-PSK (EDGE) is used, the specification is relaxed at this offset.

For SORFS measurements, measurements require a 100 kHz video bandwidth filter setting and zero frequency span.

Offset Frequency (kHz)	Resolution Bandwidth (kHz)	MORFS Limit (dBc)	SORFS Limit (dBm) (For output power ≤+37dBm)
0 (Reference)	30	N/A	Not Specified
100	30	0.5	Not Specified
200	30	-30	Not Specified
250	30	-33	Not Specified
400	30	-60 (-54 8-PSK)	-23
600	30	-60	-26
1200	30	-60	-32
1800	100	-63	-36
3000	100	-65	Not Specified

Table 1 Example ORFS specifications and measurement parameters for a GSM900 application.

Measuring ORFS on the V93000

ORFS measurements on the V93000 are performed within the V93000 Demodulation Library class, GSM_EDGE_EVO. In general, the measurement process is similar to that of making EVM measurements, in fact, the same fundamental algorithms are used, as shown in Figure 2. See Reference [4] for a detailed description of how the V93000 demodulation works.

Following the flow chart of Figure 2, first an array, either from a digitized capture or from a file, is acquired. This sampled I/Q array of information is applied to the algorithm. The user selects the demodulation type and required input parameters and from there, the MORFS and SORFS are returned from the algorithm. It is important to note that the GSM_EDGE_EVO class is extremely powerful because it also provides all of the necessary demodulation parameters such as GSM phase error and EDGE EVM as well as a non-filtered (traditional) ACPR measurement.

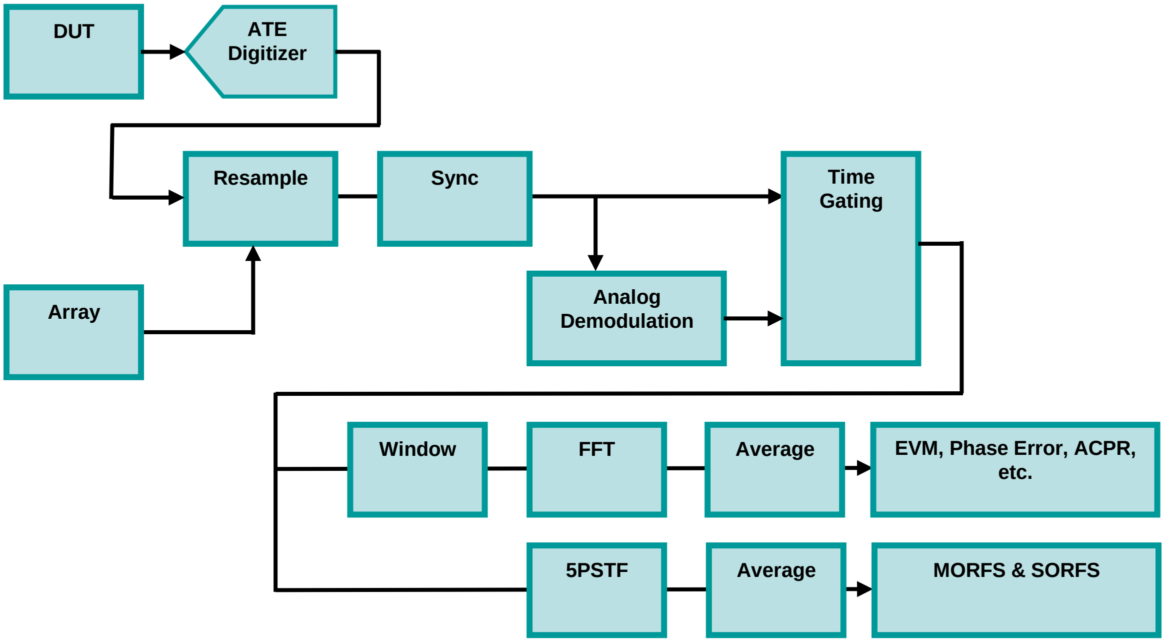

Figure 2 Flow chart of the algorithm used for calculating ORFS in the demodulation library on the V93000 [3].

MORFS Measurement Details

When multiple offsets for the ORFS due to modulation measurement are set (default behavior), the algorithm averages the power across the appropriate time segments (40 bits) of the burst with a 30 kHz resolution bandwidth, 5-pole, synchronously tuned filter placed at the center frequency of the burst. Then it compares that to a time segment of the response of the same filter placed at some frequency offset. The result is a relative power measurement using the 30 kHz bandwidth power at zero offset as a reference. For each offset specified, the DSP frequency shifts the incoming waveform and passes this frequency shifted waveform through the 5PSTF filter to calculate the correct offset, then measures the 30 kHz bandwidth power and compares it to the reference, giving a relative power measurement of signal power over the entire burst [4]. For offsets up to 1.799999 MHz, the algorithm uses 30 kHz 5PSTF filter required and at offsets of 1800 kHz and higher, the 5PSTF filter bandwidth is 100kHz as the standard states.

Although the GSM standard recommends that this measurement is performed on only the back section of the burst, the V93000 algorithm measures both the front and back data portions of the burst. Measurements occur from bit 15 to 60 and from bit 87 to 132. Measuring both the front and back of the burst has the speed advantage of providing two modulation measurements per burst.

SORFS Measurement Details

When multiple offsets for the SORFS measurement are set (default behavior), the V93000 algorithm frequency shifts the incoming waveform and passes this frequency shifted waveform through the 30 kHz resolution bandwidth, 5-pole, synchronously tuned filter to the first requested offset and samples the power of the signal over the entire burst as shown in Figure 1. The result for this measurement is the maximum of these sampled values and is reported as an absolute power measurement. The DSP then frequency shifts the incoming waveform and passes this frequency shifted waveform through the filter, samples the signal, processes the data for each requested offset, then provides the results. The 30 kHz bandwidth power at zero offset measurement is not typically made during ORFS due to switching measurements. However, the V93000 algorithm does provide both, dBm and dBc results.

Example Code

Using the V93000 demodulation class GSM_EDGE_EVO, the following code can provide MORFS, SORFS, and traditional ACPR results. This can be used as a starting point.

```
double sampleRate;      // User must provide a value for this
ARRAY_COMPLEX iqData;   // User must populate this array
DOUBLE_VECTOR offsetMORFS, offsetSORFS, offsetACPR;
DOUBLE_VECTOR morfsResults, sorfsResults, acprResults;

DEMODULATION demod("GSM_EDGE_EVO");
demod.setInputParameter("modulationSchemeAutoSelect", 0);
demod.setInputParameter("modulationSchemeManual", 1);
demod.setInputParameter("doModulatedORFS", 1);
demod.setInputParameter("doSwitchingORFS", 1);

demod.execute(iqData, sampleRate);

demod.getResult("morfsUsedOffsetsHzV", offsetMORFS);
demod.getResult("sorfsUsedOffsetsHzV", offsetSORFS);
demod.getResult("acprUsedOffsetsHzV", offsetACPR);

demod.getResult("morfsAverageResultsAllFramesdBcV", morfsResults);
demod.getResult("sorfsPeakResultsAllFramesdBmV", sorfsResults);
demod.getResult("acprPeakResultsAllFramesdBcV", acprResults);

// **** MORFS Results (dBc) ****
for (int i=0; i<(int)offsetMORFS.size(); i++)
  cerr <<  "Offset (Hz): " << offsetMORFS[i] << ", MORFS: " << morfsResults[i] << endl;

// **** SORFS Results (dBm) ****
for (int i=0; i<(int)offsetSORFS.size(); i++)
  cerr <<  "Offset (Hz): " << offsetSORFS[i] << ", SORFS: " << sorfsResults[i] << endl;

// **** ACPR Results (dBc) ****
for (int i=0; i<(int)offsetACPR.size(); i++)
  cerr <<  "Offset (Hz): " << offsetACPR[i] << ", ACPR: " << acprResults[i] << endl;
```

Results from Example Code

The above code was used to provide the following output from an EDGE modulated signal. Notice that the ACPR results differ only slightly from the MORFS results. This is expected, due to the application of the 5PSTF filter. The filter has the impact of slightly increasing the relative difference between carrier power and offset power.

Offset (kHz)	MORFS (dBc)	SORFS (dBm)	ACPR (dBc)
-1800	-107.5	-93.3	-103.3
-1200	-109.9	-96.6	-111.2
-600	-97.4	-79.9	-108.8
-400	-74.4	-65.0	-73.2
-250	-44.2	-35.4	-43.5
-200	-42.4	-33.3	-41.7
200	-42.9	-35.9	-42.3
250	-43.3	-35.2	-41.8
400	-71.5	-62.0	-72.2
600	-92.9	-74.5	-110.2
1200	-109.9	-95.8	-110.7
1800	-106.7	-92.9	-104.8

Table 2 MORFS, SORFS, and ACPR measurement results from an EDGE modulated signal.

Even though MORFS and ACPR are relative and SORFS is absolute, both, relative and absolute results are available for all three measurements.

There are numerous result parameters which can provide users with further test and debug capability. Figure 3 shows an example debugging plot from the SmarTest Signal Analyzer Tool in which the MORFS result trace is displayed. Details can be found in the SmarTest documentation.

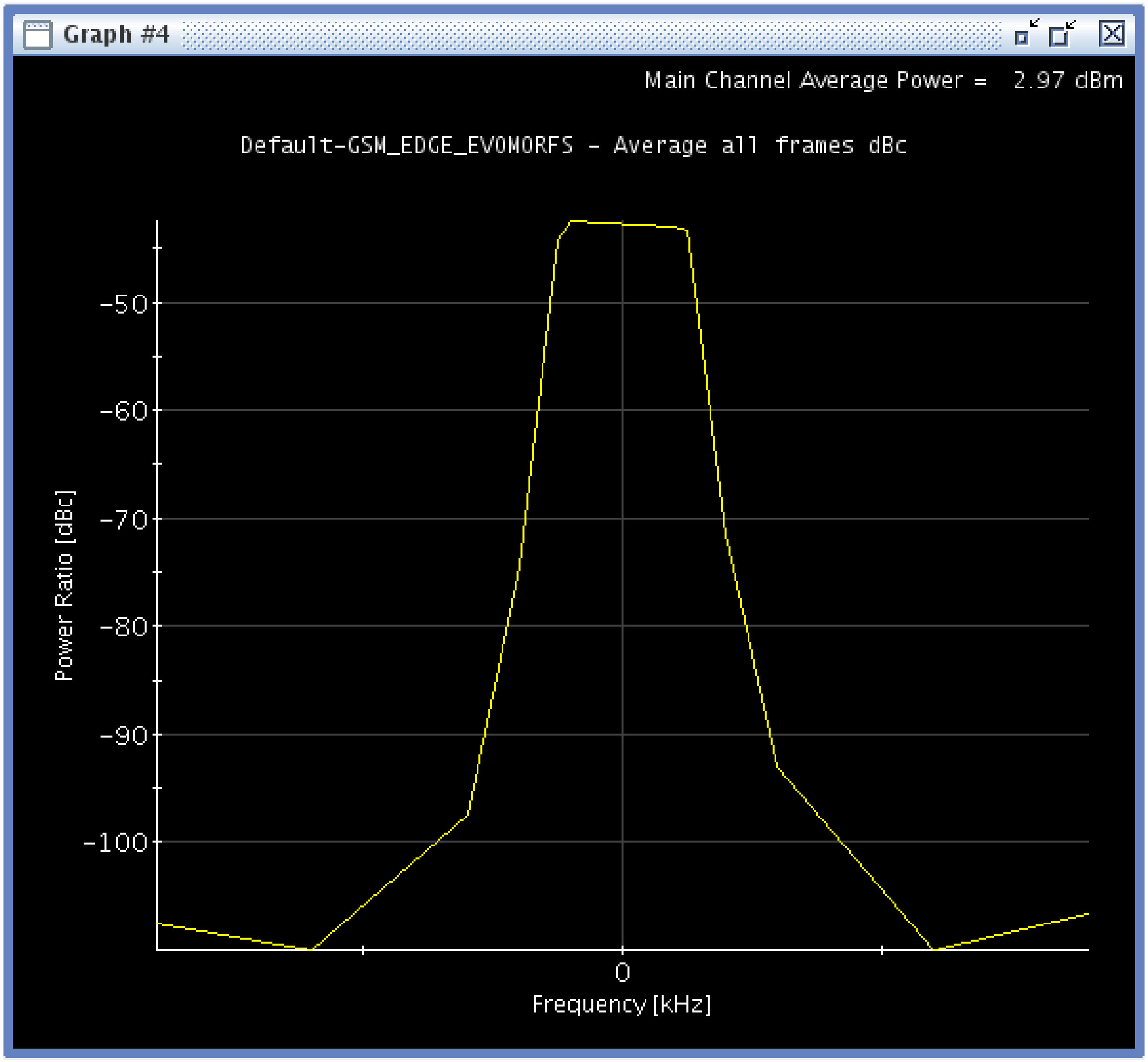

Figure 3 SmarTest Signal Analyzer plot of MORFS results.

Summary

ORFS measurements (both SORFS and MORFS) are performed within the V93000 demodulation class, "GSM_EDGE_EVO." Both, SORFS and MORFS measurements are usually performed together in a test program, but they can also be done independently through selecting the appropriate input parameter settings in the V93000. MORFS is typically performed returning relative power measurements (like ACPR) while SORFS usually returns absolute power measurements, SORFS is usually a simpler, i.e., faster measurement. Using the demodulation class in the V93000 is extremely powerful in that with a single capture, and a single API call, users can get EVM, SORFS and MORFS results and even ACPR. All of this can be executed behind the scenes in a multi-threaded process. This has a great impact on reducing test time and test program complexity.

References

[1] M. Golio, “RF and Microwave Circuits, Measurements, and Modeling,” Chapter 18.3.6 GSM/EDGE PA Design.

[2] Agilent Technologies, “Agilent Technologies Wireless/GSM Solutions,” Application Note 1312 (2000).

[3] Agilent Technologies, “Agilent 89600 Vector Signal Analysis Software,” Technical Overview 5989-1679EN (2010).

[4] Agilent Technologies, “Output RF Spectrum Measurement Description,” (2002).