MITIGATING INTERFERENCE ON AN OUTDOOR RANGE

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ABSTRACT

Making measurements on an outdoor range can be challenging for many reasons, including test article size, weather, and undesired electromagnetic effects. The challenges this paper addresses are those associated with the dense spectral environment in which measurements must often be made. Signals from external emitters must be prevented from causing interference with the measurement, and the outdoor range must not cause interference with other nearby systems. These criteria oppose each other in that if range transmit power is increased sufficiently to limit the effects of interference on the measurement, the range may cause interference to other systems. If low power is used in the range to avoid causing interference to others, the external emitter may make measurements on the range difficult to impossible. This paper demonstrates how, by using a sensitive receiver with high selectivity, one can make measurements right in the band of the interferer. By changing how the signal is processed, measurement capability is enhanced.

Keywords: Accuracy, Instrumentation, Measurement, Range, Interference, Receiver, outdoor range

1. Introduction

While the industry trend is toward indoor test facilities, many outdoor ranges are still being used today for antenna measurements. Some of these have been in use for many years and may have initially been located in areas with little competition for RF spectrum. As the population density has increased and applications of wireless technology have abounded, the potential for interference has become more of an issue.

Mitigating interference on an outdoor range is critical to making good antenna measurements. Range operators must be conscious of interfering signals that will severely reduce the dynamic range of measurements and must also consider the adverse effects that radiation from their own emissions may cause to other microwave systems, such as radars and communication systems. Operation of RF emitters on an outdoor antenna range is generally allowed only on a non-interfering basis, so overpowering an external emitter with a high power range source may not be an acceptable alternative.

Measurement instrumentation used on antenna ranges have traditionally used averaging or evenly-weighted digital IF filtering to maximize sensitivity. This type of filter works well in a pristine environment, but has a very limited ability to filter interfering signals. However, by using a more selective type of IF filter, much greater rejection of interfering signals can be achieved with only a minimal sacrifice in sensitivity. A measurement receiver that incorporates selective filtering can offer significant advantages under these operating conditions.

2. Outdoor range environment

A diagram for a typical example of an outdoor range is shown in Figure 1. A full sized aircraft with antennas to be measured is mounted on a positioner. A range like this one may be located in a rural setting on hilltops to minimize the effects of multipath. Being on top of a hill, the range has line of sight to many RF users that can be sources of interference or who may be adversely affected by signals transmitted from the range.

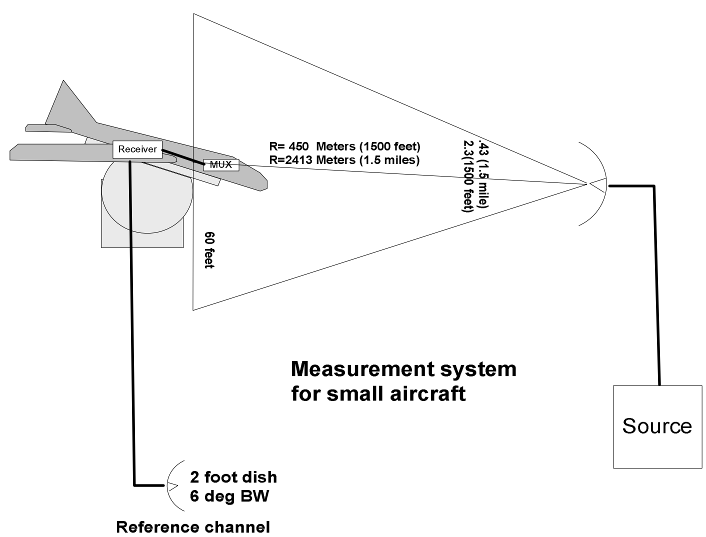

Figure 1 – Example outdoor range

For these outdoor ranges, any signals within the receive antenna bandwidth are accepted and applied to the measurement receiver. The receiver sees the desired signal plus a wide range of other signals, depending on the RF environment.

In the absence of interferers, the thermal noise floor of the receiver is normally the limiting factor to the low end of system dynamic range. However, the dynamic range of the measurement system may be less than expected if extraneous signals are not rejected by sufficient filtering. Even out of band signals may pose a problem if a receiver is used without a front end pre-selector.

The device under test (DUT) is usually rotated through a range of angles to measure the pattern of the DUT. As it rotates, the main beam of the DUT may intercept an interferer, yielding a peak response. A maximal interference condition occurs if this coincides with the illuminating test signal being in a null of the DUT (yielding minimal reception of the desired signal).

3. Signal levels for example range

The severity of this problem can be seen by considering the test conditions for the above outdoor range example. Two different range lengths of 1500 feet and 1.5 miles are examined at 2, 6, and 18 GHz. A separation of 1500 feet would be as close as one might like to be and still get accurate locations of shadows and nulls. For a target size of 60 feet, the diameter of the illuminator beam would have to be at least that large (37 degrees) at the 3 dB points as a minimum, yielding a gain of 37 dB. (For some tests, 1 dB of taper may be required, making the beam even wider with commensurate lower gain.) Assume that the source is located close to the illuminator and moderate source power of + 20 dBm is used with source cable losses limited to 6 dB. Locate the receiver in the test article and keep receiver cable losses to 8 dB.

Using an MI-750 Receiver sampling at 10 K samples per second, the noise floor of the receiver will be -110 dBm. Testing an isotropic antenna with a gain of 0 dB, the received power will be -58 dBm yielding a dynamic range (DR) of 52 dB. With no interference, this DR is more then adequate to accurately measure nulls in the pattern to a depth of 30 dB (22 dB above the noise floor).

Tables 1 and 2 show the dynamic range calculated for other frequencies and range configurations. It can be seen that in all cases sufficient DR is available. The power levels for the 1.5 mile and 1500 foot ranges are similar as the beam is kept at 60 feet in diameter in both cases. This yields similar power densities and therefore space losses.

1500 foot outdoor range (10 K samp/sec)					
Freq (GHz)	Illuminator Diameter	BW (deg)	Gain (dB)	PR DUT (dB)	DR DUT (dB)
2	16	37	37	-49	61
6	5.3	37	37	-58	52
18	1.8	37	37	-68	42

Table 1

1.5 mile outdoor range (10 K samp/sec)					
Freq (GHz)	Illuminator Diameter	BW (deg)	Gain (dB)	PR DUT (dB)	DR DUT (dB)
2	28	1.3	42	-58	52
6	28	.43	51	-58	52
18	9.3	.43	51	-68	42

Table 2

Now consider the case where there is an interferer, and as the DUT is rotated, the interfering signal impinges on the peak of the beam. The amplitude of the interfering signal may be stronger than the received DUT power. If it is 20 dB higher and the noise floor of the receiver is 52 dB below the DUT peak response, the interferer must be filtered by 72 dB to prevent de-sensitization of the receiver.

One might consider increasing transmitter power to swamp out the interference, but this can create other problems. To get back just 30 dB of DR lost to interference, the transmitter power has to be increased to 100 watts from 20 dBm (0.1 watts). This is expensive and also may cause interference to other nearby users, who likely have right of way on this frequency. Putting a pre-amp on the front end of the receiver does nothing, as the interferer is increased along with the signal.

Our problem is not sensitivity but selectivity. The judicious use of filtering to eliminate the effect of the interferer provides the best solution to this type of problem. Filtering options in the instrumentation chosen for this measurement can greatly impact the quality of test results.

4. Measurement instrumentation options

In the presence of interfering signals, the ability of the receiver to separate the unwanted signals in the test environment from the desired test signal sets the system dynamic range. Measurement receivers have a varying degree to which they can distinguish between desired and undesired signals. There are several factors which affect the receiver's select the desired signal and reject the undesired one.

Measurement receivers typically have an open mixer at its input. This is done to allow for fast tuning times. Once the LO has settled, a measurement can begin. The lack of a front-end RF filter, while optimum for switching speed, has the problem of allowing a multitude of signals to mix down to the IF frequency, increasing the number of signals that have to be filtered out. These additional signals are called receiver spurious responses.

Most measurement receivers employ the heterodyne architecture. Therefore there is at least some analog IF filtering to eliminate some spurious signals produced in the process of downconversion, which also gives the receiver some degree of selectivity. Additional digital IF filtering or averaging is usually performed to further reduce the noise power bandwidth.

There are four common ways that filtering is performed:

None - as in a power meter,
Average - coherently average N samples
FFT - separate data into frequency bins
DSP - FIR or IIR digital filter

Averaging is equivalent to an evenly-weighted FIR filter. Both result in a sin(x)/x spectral distribution that offers minimal rejection of interfering signals, unless the interfering signal happens to align with a null in the response. The first sidelobe of the spectral response of this type of filter only offers about 13dB of rejection to an undesired signal.

The averaging type of filter may be chosen for a measurement application to minimize the noise power bandwidth when interfering signals are not present. However, when such signals are present, a more highly selective filter is desired. This type of filter has slightly more noise power bandwidth, but with the advantage of large improvements in out of band signal rejection.

By using different weighting of taps in an FIR filter, the characteristics of the filter can be changed to balance between selectivity and noise power bandwidth. A highly selective filter provides the ability to process the desired signal while rejecting the undesired signal, but at the expense of slightly more noise power bandwidth. While a less selective filter allows any undesired signals that are present to influence the measurement of the desired signal.

Instruments designed for bench top applications typically use averaging type digital filters, because cabled test setups don't typically have interference. In shielded chambers, interference is also not typically an issue. However, for outdoor ranges, additional filtering capability can make the difference between impossible and viable measurements.

5. Filter performance comparison

The MI-750 receiver provides a choice of three different filter types that can be selected to optimize measurements on a given range. Figure 2 shows the spectral characteristics of these three filters. The averaging filter produces the least rejection, about 13-20 dB close in and only 45 dB farther out. The low noise filter has 40 dB rejection close in and 70 dB farther away, and the high selectivity filter has 95 dB close in and 105 dB far out. The trade off is 1.5 dB and 4 dB loss in thermal noise rejection for the low noise and high selectivity filters, respectively. But in many cases, thermal noise is not the primary issue, and this is a good trade off.

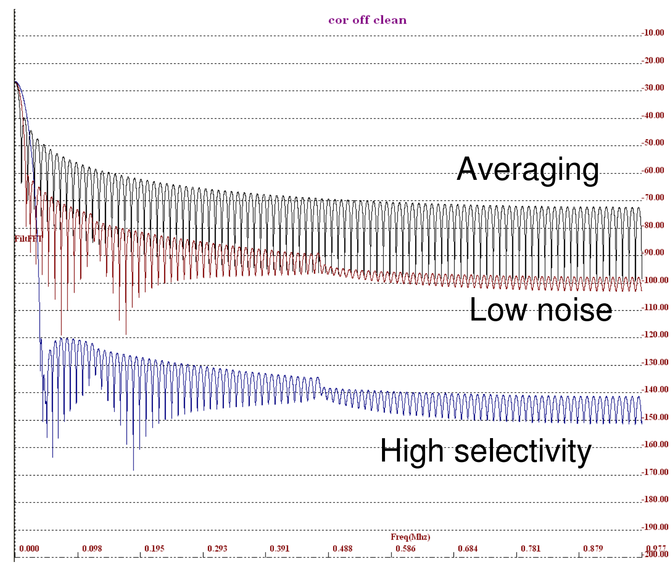

Figure 2 – MI-750 Filter Types (10 KHz)

With an interfering signal 50 KHz away from the desired test signal, the output of the receiver is shown in the next 4 figures for 4 sample rates: 100,10,1,0.1 KHz. Each plot has three data sets:

- the amplitude of the receiver output,
- the selected filter pass band, and
- the spectrum of the receiver output.

The spectrum clearly shows all residual unfiltered signals, even those that lie below the receiver noise floor. The number of samples was varied such that each plot is for 1 seconds worth of data. With the 100 KHz sample rate

(Figure 3) much of the interfering signal comes through as is expected, and it is right on the receivers edge.

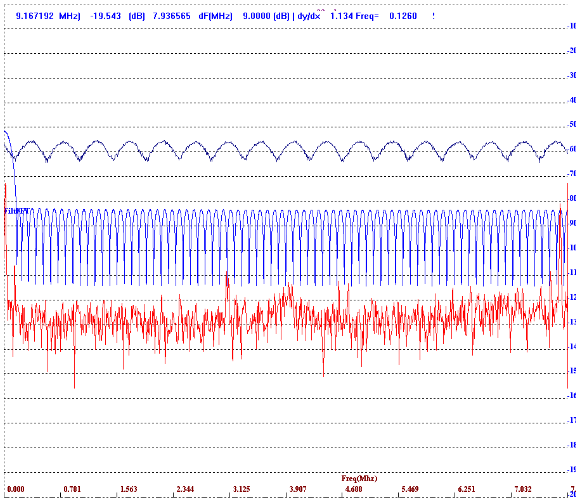

Figure 3 – 100 KHz

At 10 K samples per second (Figure 4) it is totally eliminated. There are a few extraneous signals from other sources still present but they are 20 dB below the noise floor.

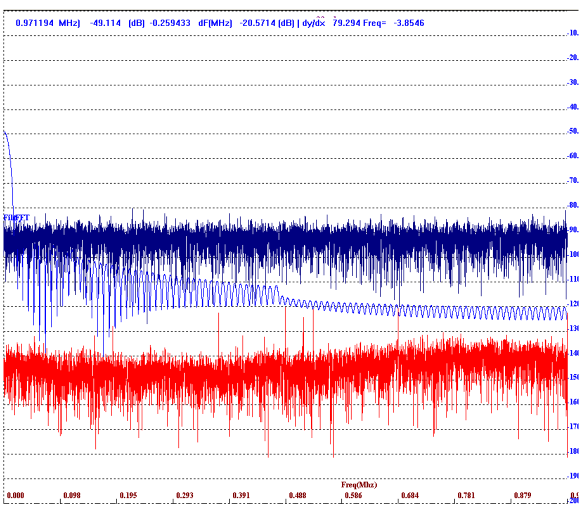

Figure 4 – 10 KHz

At 1 KSP (Figure 5), noise reduction continues as the remaining signals are filtered out. Note with averaging they would have decreased by 10 dB at most, and likely only 3 dB. With moderate filtering, they are below the noise floor yielding full receiver DR.

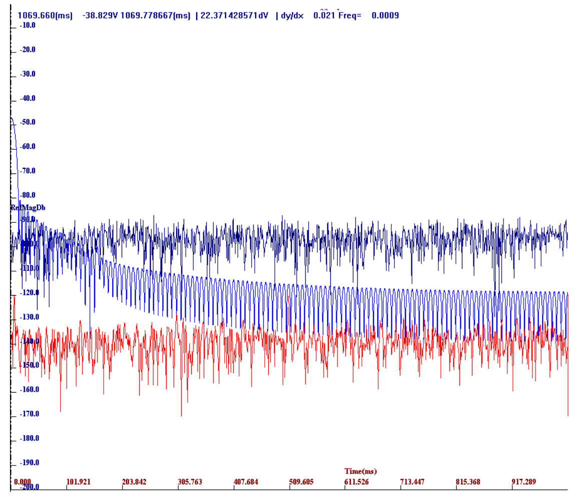

Figure 5 – 1 KHz

At 100 Hz (Figure 6) we continue to get increased sensitivity indicating that the interference has been mitigated.

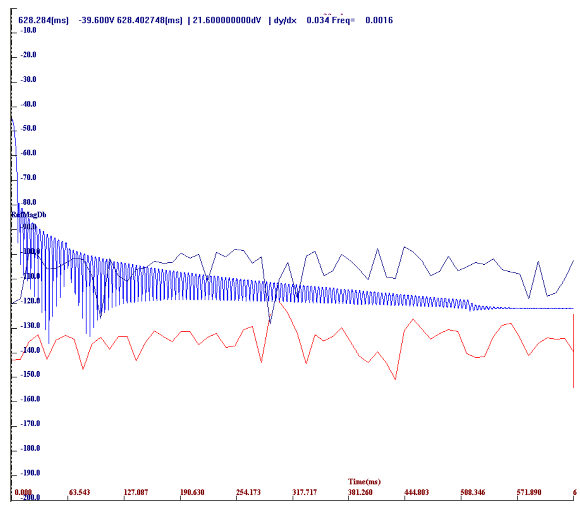

Figure 6 – 100 Hz

6. Filtering out interference

In an outdoor environment, the receiver sees the desired signal plus a wide range of other signals. Tuning the MI-750 in the lab to the HF spectrum provides an example of a dense spectral environment. The desired signal is produced from a source radiating through an electrically small antenna and the receiver also operating from an electrically small antenna. Figure 7 shows the entire spectrum presented to the receiver.

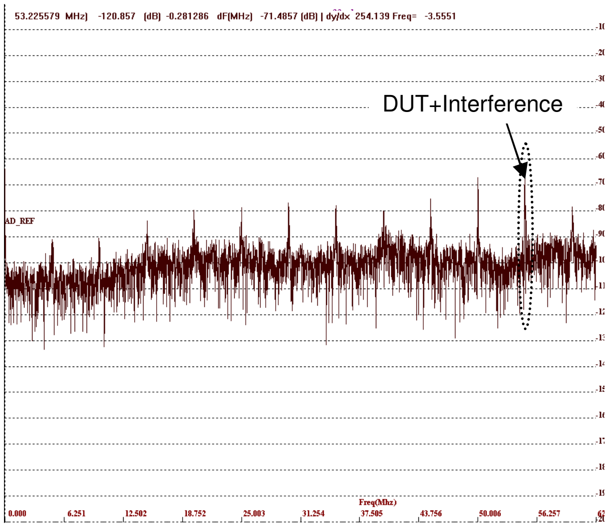

Figure 7 – RF Spectrum (10MHz – 65 MHz)

A wide range of signals are observed on the spectrum input to the receiver. The entire noise floor is elevated by the noisy RF environment. This produces the "grass" of varying intensity. There are also a number of strong interferers that appear as lines.

Figure 8 is zoomed in around the desired signal, showing that it sits about 7 dB down in amplitude and 50 KHz on the lower side of an interferer.

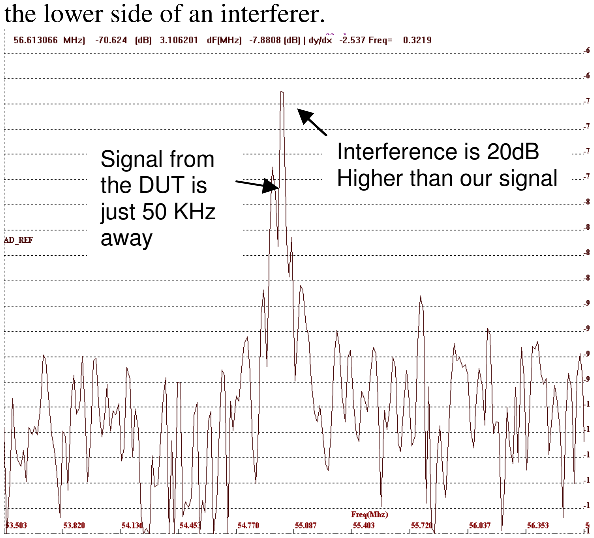

Figure 8 – RF Spectrum Zoomed

For this example, the MI 750 receiver is set up to sample the signal at 125 MHz and is producing a 10 K sample per second output. Both the time domain output (over a 1 second time period) as well as the frequency spectrum of the receiver output (+/- 5 KHz with 1 Hz resolution) is captured.

Figure 9 shows how using a receiver with highly selective filtering reduces the interference below the noise floor. The receiver output has only the thermal noise associated with the receiver sensitivity (about -100 dBm at 10 KHz in the HF band). The remaining spurious signals seen are part of the transmit source signal, which was verified by turning off the source.

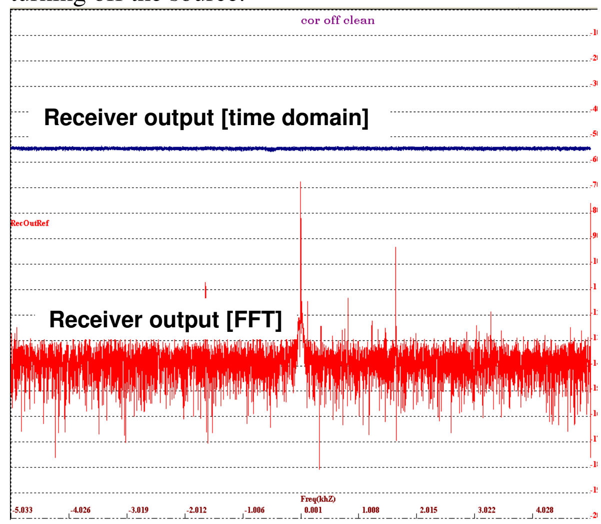

Figure 9 – Selective Filtering

In contrast, Figure 10 shows that when averaging is used, the filtering is insufficient to reduce the interference. The interference modulates the receiver output producing significant measurement errors. Looking at the spectrum of the averaged receiver output, one can see that much of the interference signal aliases back into the receiver output adding significant noise. It is attenuated but not enough. Here the receiver noise floor is set by the interference and not the thermal noise. The receiver has been desensitized by the interference.

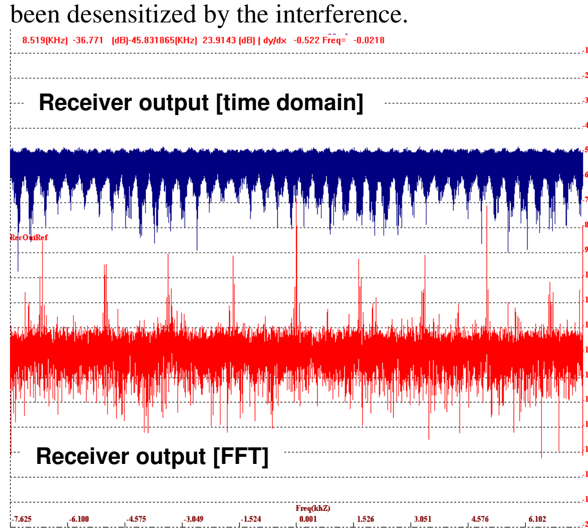

Figure 10 – Averaging

7. Advantage of a selective reference channel

For the range that has been discussed, a reference signal is derived from the illumination beam. It is received with a 2 foot dish. The dish has side lobes that move with frequency and hence could pick up interference when one lands on an emitter. To enhance reference sensitivity, the MI-750 filters the reference channel to the same bandwidth as the signal channel. This does two things for the range performance, it filters out interference on the reference channel and reduces the noise power in the reference channel. The MI-750 Receiver can maintain phase lock with reference power close to the noise floor. The reference channel noise affects the measurement when the A/R calculation is done to obtain relative gain and phase. Hence for most applications the reference should have 60 dB dynamic range or be at least 10 dB above the DUT signal.

For the ranges analyzed in table 1 and 2, about 150 feet of reference cable is used with 6, 12, and 30 dB of insertion loss for the reference cable at 2, 6, and 12 GHz. In all cases, in excess of 60 dB of dynamic range is achieved on the reference channel with a 10 KHz sample rate, and this is without using remote mixing. The reference DR increases as the sample rate is lowered just as with the signal channel. This ensures accurate measurements without having to use remote mixing.

8. Summary

A measurement instrument that offers a choice of highly selective filtering, such as the MI-750 Receiver, is a valuable tool that can increase performance and enhance the measurement capability of an outdoor range. By appropriate use of filtering, the adverse affects of undesired interfering signals can be minimized.

8. REFERENCES

[1] Poole I. “Understanding Receiver Selectivity” Monitoring Times, December 2000

[2] Slater D. “A Hilbert Transform Based Receiver Post Processor”, AMTA 1991

9. ACKNOWLEDGMENTS

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