Anritsu

POWER MEASUREMENT IN TODAY'S COMMUNICATIONS ENVIRONMENT

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Linking the World

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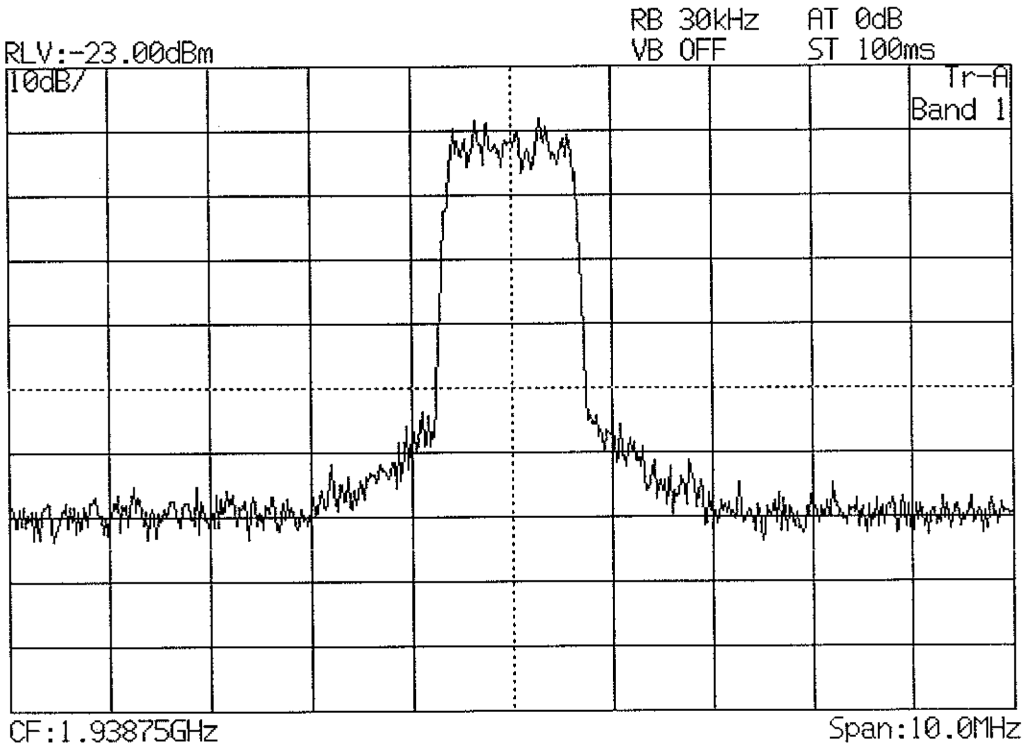
Introduction

What industry is demanding is a realisable and accurate way to measure complex modulation waveforms that are becoming widely adopted by the communications industry such as GSM and CDMA. The ML2407 and ML2408 power meter product enhancements to the Anritsu power meters range illustrates the dilemmas facing the industry.

The Key problem explained:

Code division multiple access is a modulation method that allows multiple users to use the same transmission channel concurrently. This is made possible by the use of spread spectrum techniques and a digital group of Orthogonal codes called Walsh codes. For any transmission if the Walsh sequence is known the transmitted data can be recovered by correlation. Other signals by definition are orthogonal and will correlate in to noise. The resultant total transmitted waveform is complex, constantly changing and directly proportional on the data (payload) and the number of users per channel. The channel if observed in the frequency domain will look like noise. **(Fig1)** Each noise peak being analogous to the summation of many channels containing a transmitted symbol 1 at that instant in time while a trough represents many zeros.

(Fig 1) Spectrum of an N-CDMA signal



The peak to trough ratio is called crest factor; this and adjacent channel power are a good measure of system performance. Typically in a fully loaded channel for an IS95 CDMA signal this ratio is of the order of 10 to 12 dB; whilst a wideband CDMA signal could have a crest factor of 15 dB. Why is this important? The base station operator needs to transmit this signal to all users in the cell hence the need for a high power linear amplifier. For this to be able to cope with the possible peak powers, the amplifier need to be backed off substantially or designed to cope.

An accepted method to quantify the amplifier's tolerance is similar to the measurement of 1 dB compression point. The deviance of the amplifier from the linear characteristic is measured using generated standard signal. The crest factor of this signal before and after the amplifier can be measured. If the crest factor changes then this is due to compression in the amplifier. The similar measurement on a spectrum analyser is adjacent channel power this is a direct measure of the change in the sidelobe power brought about by the amplifiers compression.

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Technologies available

The spectrum analyser is good for making relative measurements and is often used to measure the side-lobe regeneration of an amplifier in compression. Given the cost and poor absolute power accuracy of the spectrum analyser the lower cost power meter option is often used. The Power meter options are therefore further investigated and explained.

Table 1 Spectrum analyser – comparative level accuracy

Total uncertainty of common instruments		
Power Meter	~ 4.5%	(0.2dB)
One Box Tester	~ 12%	(0.5dB)
Spectrum Analyzer	~25%	(1.3dB)

A standard power meter comprises two parts the meter and a sensor. Normally the meter remains unchanged and the sensor to fit the measurement applications is selected. The selection criteria are normally: type of connector, dynamic range, sensitivity and frequency of operation. Commercially available sensors will be available based on one of two technologies. Absorption as in thermistors, thermocouples or thermopile and Rectification containing a number of silicon Schottky detector diodes. Each has its strengths and weaknesses for specific applications.

The thermocouple or a thermopile, an advancement of the thermocouple, is based on the RF heating of a item to produce an output voltage. This output voltage is a result of either the Thomson emf where electron migration is proportional to the temperature gradient within a metal and the Peltier effect, the diffusion of electrons at a dissimilar metal junction. The combined process the Seebeck effect is used in the design of the modern thermopile an array of series connected optimised thermocouples. Having now designed a temperature sensor all that remains is to shrink the size and integrate it with a terminating resistor so that the applied RF heats the resistor and the change in temperature is measured by the series thermocouple. From this construction it is evident that the limiting factor will be the response time and is directly proportional to the thermal mass of the thermopile. The ability of the applied RF power to change the temperature of the measuring terminating resistor leads to the other limitation; the sensors dynamic range. At lower power levels the RF heating effect is small and results in a very low output. Typically the lowest limit of detection is around -25dBm and at this limit the temperature resolution is of the order of 1,000th of 1 degree Centigrade. The main advantages of a thermal sensor fall into two categories. Firstly whatever the applied signal the heating effect is always a true indication of RMS power. Therefore this sensor type can be used for measuring any modulation scheme including Fast I/Q modulation like IS95 and Wideband CDMA, Noise and multiple CW signals. The second category is that these sensors have a large frequency range and will operate from DC through to many GHz limited only by how good a termination can be made.

The rectification sensors are typically zero bias Schottky barrier diodes. Depending on the implementation there may be more than one diode and often a pair of devices are used to get greater sensitivity. As with all active components there are constraints on the diode manufacture and packaging which relate to user limitations and restrictions. The first obvious restriction is the device parasitic which would ultimately limit the frequency response. However some other factors like the diode barrier height will set the potential required to overcome the barrier and ultimately influence the sensitivity of the diode at lower levels. Analysing the linear model of the diode the video impedance of the diode and the detector output capacitance will determine the effective bandwidth. Note that the video impedance changes with level and will ultimately limit the output sensitivity. Although the temperature sensitivity of the

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Schottky barrier diode is not as great as a point contact diode, the effect on detector sensitivity is still significant and will improve the performance with lower temperatures. If we now consider the diode non-linear characteristic we find that rather than the output voltage being proportional to the applied power the diode will start to envelope detect resulting in the output voltage falling away from the theoretical square law.
In order to utilise the diode sensor to the best effect then characterisation and correction will play an integral part of any design. At Anritsu each diode sensor is fully characterised with correction factors electronically stored to a sensor Eeprom, correcting automatically for temperature frequency and level. The Anritsu chosen correction scheme adopted utilises the common and established practice of Cal factor this compensates for the diode frequency effects at a constant level of 0dbm. To complement this an Anritsu specific technique is also used. This technique measures the sensor at specific known stimuli to generate a set of best fit equation polynomials describing the diode level response at specific temperatures and frequencies. This polynomial equation allows interpolation techniques within the meter to accurately determine the measured power to a high degree of accuracy.

The optimum performance is achieved when an 4th order equation polynomial is used. Despite the correction requirements the main advantage of using a diode sensor is that of speed. The response time is much faster than the heating time constant of the thermal equivalent. Another significant advantage is the dynamic range because at levels below -20dBm where the thermal sensor is running into noise floor, problems the diode sensor is in the linear useable square law. The diode sensor has its disadvantages though, the most significant is the inability to measure accurately a modulated signal at high signal levels (out of square law) and large modulation bandwidths. If the modulation exceeds the sensor's bandwidth, errors will result. These errors will be level dependent i.e. proportional to the correction factor and the nature of the modulation. The errors occur because all the correction tables have been constructed using a sinusoidal stimuli. A unit could theoretically be characterised for a particular modulation type but this instrument could then only be used with that specific modulation only. A smaller drawback is that the diode sensitivity at very low frequencies is poor and coupled with the requirement for diode protection by a coupling capacitor makes diode sensors un-useable below 10MHz.

Summary of sensor characteristics

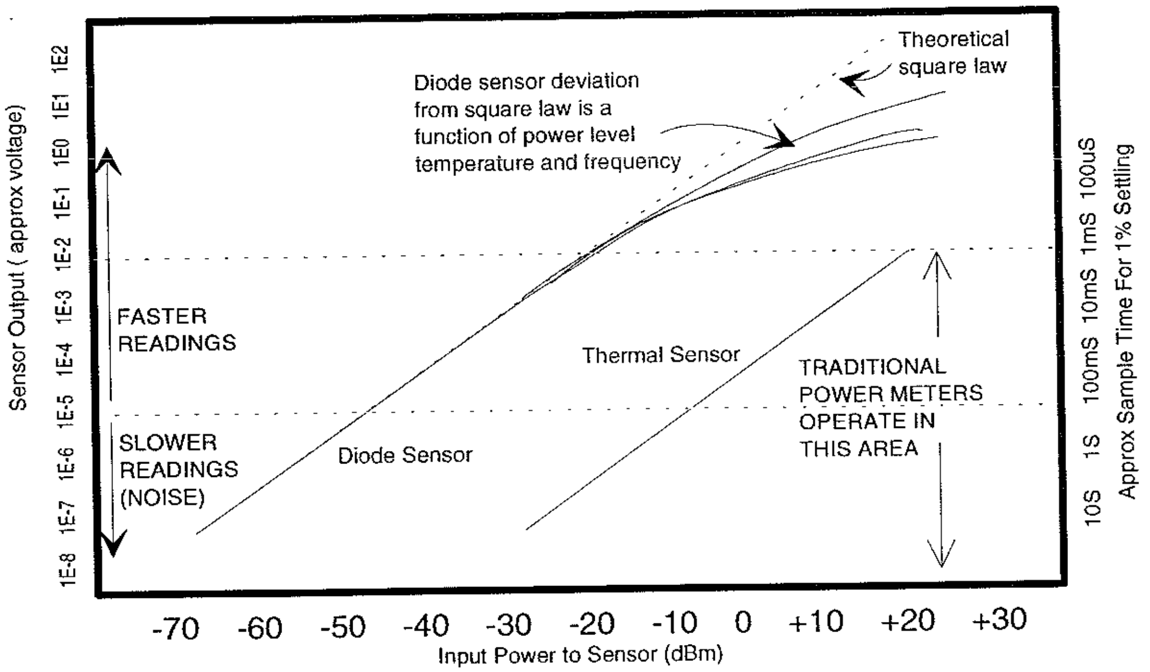


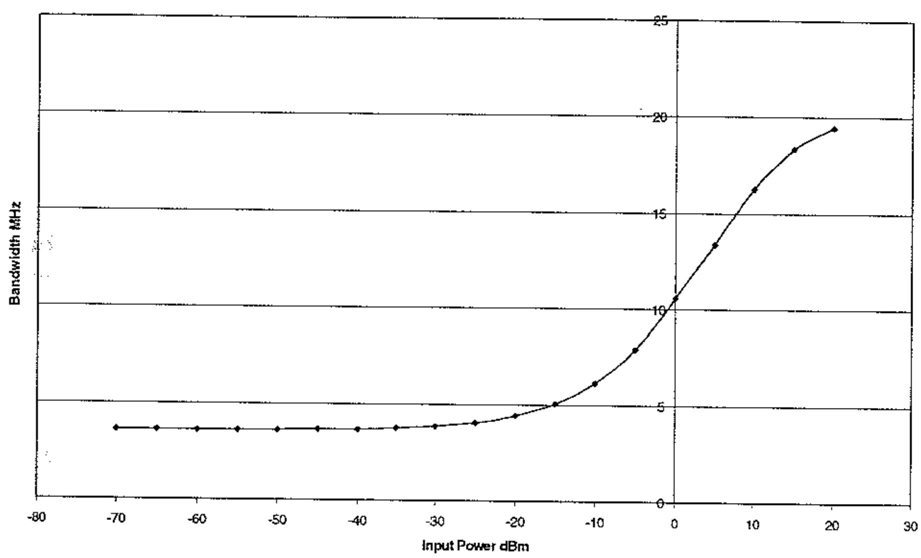
Diagram 2: Sensor Sensitivity vs Signal Level.

The Zippy project

Having covered the main issues associated with power meter design, I would like to share some of the design challenges encountered in the latest update to the Anritsu power meter family, the new faster Zippy meter and then continue to outline future useful trends.

The design choices facing the design team could have been phenomenal in producing a general purpose instrument to suit all market options and required careful market appraisal. The zippy project remit was to address the IS95 CDMA requirement without a total redesign of the meter. The obvious sensor to use was the zero bias Schottky diode. The selection criteria being its superior response time. The current range of sensors although adequate for GSM still did not have sufficient bandwidth to handle the 1Mhz IS95 CDMA signal. The differential diode structure loading needed to be reduced to attain the speed requirement. However analysing the diode loading carefully revealed that there is a practical limit to the bandwidth equation.

Bandwidth v Input Power for 20MHz Detector (SPICE Model)



The graph shows the maximum attainable bandwidth for a given minimum loading of the diode and clearly shows that although a headline figure of 20MHz bandwidth could be quoted this would only be true at one high power level. A reduction of the power would consequently reduce the available bandwidth to a more realisable 1-3MHz and indeed a feedback technique was used to limit this bandwidth and make it constant with level. All be it at the reduced IS95 requirement of 1.25MHz. Having achieved a sensor element that is fast enough the next task is to get the signal to the meter. Currently because of the low signal levels involved in the detection process the sensor has discreet buffer amplifiers with gain to minimise connector and cable loss. In this day and age there are a significant number of manufacturers with new and faster operational amplifier to make the right selection from; however the fastest is by no means the best.

A drawback with fast op amps and indeed a figure of merit that is not often quoted on operational amplifier specifications sheet is flicker noise. Long term drift tests reveal that fast amplifiers reduce the system performance due to their inferior flicker noise characteristics. The compromises do not end here given that the new sensor requirement has a must criteria of interoperability with existing sensor cables and meter units. The analysis of cable group delay meant that cables in excess of 10m would result in significant degradation of performance. The solutions available were to restrict the cable length or provide cable equalisation.

The meter modifications

As already discussed the signal channel would require an upgrade with a suitable fast and friendly flicker noise part. The meter is comprised of many linear gain stages with different gains that are selectable. The relevant signal channels with sufficient gains is then routed to an Analogue to Digital converter where the resultant voltage can be converted and corrected to display the reading of incident power. The limiting part would appear to be the converter needing to be fast enough to cope with the increased bandwidth. This is not strictly true. If the speed of making the measurement can be increased the existing high resolution, accurate sub 1 MHz A to D converter can be used. Given the statistical nature of a CDMA waveform the probability of attaining certain power is well defined and can be profiled. If sub sampling is used, a true representation of the applied signal can be composed if a significant number of samples are taken and averaged. The down side is that the time to make the measurement increases. From our findings keeping the same converter enabled us to achieve a sensible response time sub 5 seconds for a crest factor measurement with the added benefit of very good resolution unobtainable with fast converters.

The not so obvious problem of gain stage selection presents more of a challenge and hides two potential problems that are related. Firstly handling signals with large crest factors requires that at the changeover point a hysteresis equivalent to the crest factor is selected. The average of a fully loaded signal with a crest of 9dB in a particular gain setting would need to be at least 9 dB lower than the saturation level of that channel to faithfully reproduce the applied waveform. When this average signal level rises above this threshold then the new gain stage must have sufficient resolution to cope with the troughs within the signal.

This imposes a new requirement on the gain selection engine control loop and imposes a reduction of useable range per channel ultimately this resulting in the requirement for more channels to maintain the accuracy. There is a minor playoff that can be adopted in that some saturation can be tolerated providing the value is similar to the resolution error.
The second is as a direct result of a feature offered within the Anritsu power meter that profiles the power of an applied waveform. When an applied pulse crosses the selection boundary and continues through to the maximum signal of the next range only to then fall moments later back to a minimum in first range the selector functions correctly and tracks the signal. However the first lower signal level channel will saturate with the applied signal and as a result will take a long time to recover. This is not a predictable state and is proportional to the overdrive signal. This imposes another requirement on the selector switch which either needs to be in the signal channel and fast acting - impractical or adopt some measure to prevent saturation of a signal in an intermediate range channel. This is not the only problem associated with the gain selection regime. The operational amplifiers used within a gain stage have slew rate limitations which are dependent on the speed of the selected device and also in conflict with good flicker noise as discussed earlier. If a signal traverses the full channel dynamic range quickly the operational amplifier will lag this transition but the new range channel could have been selected and produce valid readings much earlier than the first channel has responded. This produces a inconsistency in the connection of any two gain ranges.

The future and Wide-band CDMA

There are solutions for measuring these wide-band signals with existing technology, that of the thermal sensor and a diode sensor below -25dBm. These will report the True RMS Value of any modulated signal. The drawback is the limited dynamic range of approximately 40dB. Market research indicates that this is not ideal and customers demand a dynamic range of 70dB minimum. Faced with this challenge designers are forced to consider enhancements to the diode as this device inherently has the greater dynamic range. You will recall that there are two areas of operation when using the diode sensor . The linear region where the bandwidth is not a limiting factor and the diode follows the true RMS power. The only limiting factor is the speed of obtaining a stable reading which is proportional to the applied signal level. The smaller the signal the more averaging is required and the greater the time taken. The second non linear region observed at higher power levels is the problem are by being bandwidth dependant and peak envelope responding requiring correction for a true RMS reading.
There are two options available. Option 1 to widen the bandwidth of the diode sensor as with the zippy project and optimise for the low level noise floor degradation or Option 2 Consider the synario described in fig 2.

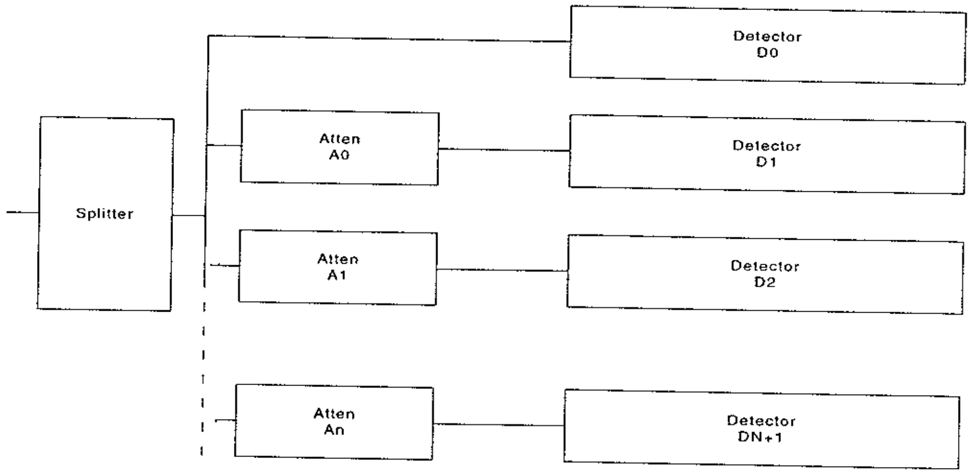


Fig 2.

a group of diode detectors each preceded by a fixed attenuator and a splitter supplying the same signal into all the channels. The attenuators can be fixed such that the operational signal range of each detector is staggered and kept within the linear operational region for each detector. Using this technique with the appropriate channel selected for the applied signal level would result in each diode operating in its linear region and producing the wanted true RMS power. The main task is to optimise the number of ranges such that the diode settling time and dynamic range criteria are met for the required market application. Also bearing in mind that the maximum input signal is limited by the splitter loss, and the total power handling of an detector with no attenuator in front of it. The splitter is also subject to optimisation as it is more difficult to attain a broadband match for a splitter with a larger number of fan outs.

Summary

The benefits and drawbacks of power meter sensor have been considered and I have demonstrated that with the appropriate sensor meter combination all the main market requirements for measuring modern complex modulated communications signals can be achieved. With sufficient understanding of the measurements required and limitations imposed by the measurement instrument including the selection of the correct sensor technologies the communications industry can be served with accurate and fast measurement.