NPL Report CEM 8

REPORT

Power Measurements for the Wireless Communications Industry

A Report on User Requirements

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John Ascroft

September 1998

NPL

National Physical Laboratory

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This report describes results of a research study to investigate the current and future rf and microwave power traceability requirements for the wireless communications industry. Recommendations for power measurement methodology and specifications of a measurement system are also discussed.

OPEN REPORT
ISSN 1369-6742

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1. Introduction

As the wireless communications industry has continued to expand activity has increased in the area of digital communications such as GSM (Global System for Mobile Communications) as shown in Fig.1. The anticipated growth of the digital GSM operating system was previously underestimated and revised forecasts now anticipate world wide users totalling 120 million by the end of 1998. These digital technologies are expected to maintain an almost total domination of industry growth as shown in Fig.2.

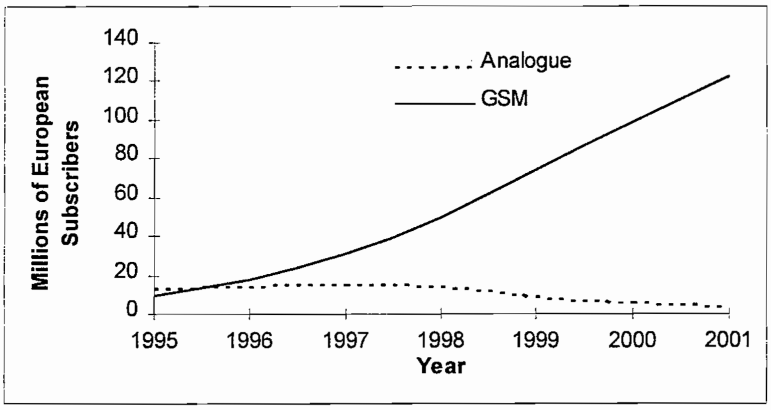

Fig.1. The anticipated growth of European Subscribers to the Analogue and digital GSM network [1].

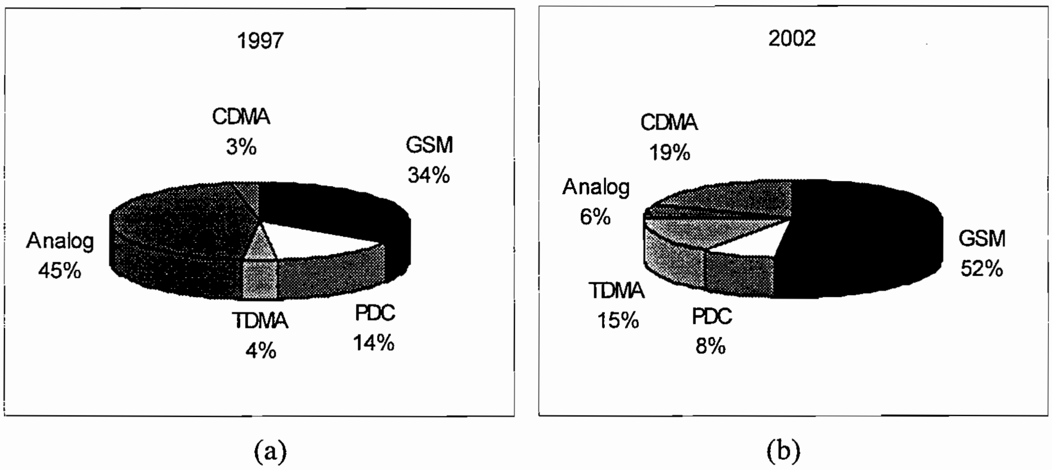

Fig.2. a) Market share of the various operating systems currently available. b) Anticipated market shares for 2002 [2].

Digital operating systems such as GSM, CDMA (**C**ode **D**ivision **M**ultiple **A**ccess), TETRA (**TE**rrestrial **T**runked **RA**dio) and DECT (**D**igital **E**uropean **C**ordless **T**elecommunications) have many advantages over the first generation analogue systems such as an increase in information capacity for a reduced rf spectrum occupancy, enhanced call quality and higher data security. However, there has also been an increase in the complexity of these operating systems and new validation techniques are required. A common specification which operators must conform to is the power output for both the handset and the base station. Manufacturers conforming to power specifications require suitable test equipment which must be traceable to power standards. Pulse power measurement traceability is vital to support product specification, test and calibration and public health and safety.

NPL has been tasked by DTI to provide traceable power measurements for the wireless communications industry. Recognising that this is a new area for rf and microwave guided wave power measurements an extensive literature search has been undertaken and an industry group has been established to advise on requirements. Communication between NPL and industry has been by private discussion and also by a group discussion in the form of an open forum. Several conclusions were drawn from the open forum and these will be discussed in the following sections.

Results from the literature survey indicated extensive global activity in this field but with minimal consideration being given to the problems associated with measuring the power levels of complex modulated digital signals.

2. Why pulse power traceability is required

It was acknowledged by industry that power sensors which are used to measure pulse power require a traceability route other than that currently provided by the manufacturers using CW (**C**ontinuous **W**ave). The determination of a sensors calibration factor in CW and transference of this value to pulse measurements can result in incorrect measurements being made in some circumstances. For example, a calorimetric device such as a thermistor or thermocouple sensor calibrated in CW cannot be used to measure the pulse power in the complex modulation schemes used in wireless applications because of the slow rise and fall times associated with these devices. Only diode sensors which have fast enough rise and fall times to respond to rapid changes in amplitude can be used to measure peak power to current specifications. In some circumstances even a diode sensor (which has relatively fast rise and fall times compared with a calorimetric device) calibrated in CW may not be transferable to a certain type of pulse measurement, this is explained in section 4.

3. Industry's Technical Requirements

Industry requirement for rf and microwave power traceability will ultimately depend on the actual telecommunication standard and the specific section of the standard to which they are conforming. The majority of standards define power limits in time and in the frequency domain. The instrumentation used when testing conformance to each of these specifications can be different. When conforming to a power time template the requirements are for a fast responding device such as a diode based pulse power sensor. Most current power specifications require the average power and the peak power in a pulse or burst of rf to be measured and for this value to be within defined limits.

For the power limits in the frequency domain, referred to as the output rf spectrum, a resolution bandwidth must be set about the carrier frequency. This normally cannot be done using diode power sensors and a spectrum analyser is usually employed. The amount of rf spectrum over which power is measured is determined by the resolution bandwidth.

Research has shown that pulse power traceability is required up to 3.5GHz for current mobile communications. Fixed link, point to point communications currently operate up to and beyond 40GHz. Future wireless communications are expected to extend up to 100GHz. Power levels range from -70dBm to +46dBm for the current UK operating systems such as GSM, DECT and TETRA. Future operating systems are expected to be either a combination of CDMA and TDMA (**T**ime **D**ivision **M**ultiple **A**ccess) or W-CDMA (**W**ideband CDMA). This is an area currently under review through UMTS (**U**niversal **M**obile **T**elecommunication **S**ystems) which is aimed at standardising third generation systems.

For higher frequency fixed links the current specifications require a measurement of average power over the total transmission time. Power traceability to CW is the only requirement and therefore the needs for the high frequency operators are currently being met. A move is expected towards a TDMA based operating system at the higher frequencies in order to increase information capacity. It is envisaged that the measurement service will be adaptable to the requirements of the higher frequency operators when they come into operation.

4. Power Measurement Methodology

The limits on the average power, as defined in the ETSI specifications, can vary for the different operating systems between ±3dB and ±1dB of a reference level, where the reference level is defined as either the specified transmit level or the average power. It is the maximum possible average power measured, i.e. the average power plus the uncertainty in the measurement (derived from the systematic and random uncertainties) which should be within ±3dB or ±1dB of the reference level.

Consider a transmitter power of +46dBm in which the average power must be within ±3dB. If the error in the measurement of the transmitter power is ±3dB or more then it is impossible to conform to specifications. If the error in the measured value is ±1dB then the ±3dB limit tightens to ±2dB because of the uncertainty in the average power measurement. The error in the measured value must be included when deciding upon a pass or fail for a particular test.

Calibration of a diode peak power sensor is particularly important for power levels which are not within the square law operating region of the diode. Outside this region, manufacturers can employ a mathematical model to compensate for each individual diodes non-linearity. These techniques will vary between manufacturer and diode therefore pulses with power levels outside the limits of the square law region must be traceable to national standards.

Further problems can occur in measuring the peak or average power in a burst and these are related to the sensor's video bandwidth (often just called sensor bandwidth) which is very different to the wide rf bandwidth. The sensor's video bandwidth is generally much smaller than the rf bandwidth and depends on the diode sensor type. Sensor bandwidths can range, for example, between 100kHz and 35MHz whereas the rf bandwidth is ultimately defined by the connector size of the sensor and can be greater than 40GHz.

Consider a theoretical rectangular train of pulses each with a pulse width of 5µs. The sensor's video bandwidth must be larger than 1/5µs (i.e. the rise time of the sensor must be much less than 5µs) or there will not be a true representation of the pulse and any peak power or average power measurement of the pulse may not be correct. Experiments have shown that for the case where a pulse to be measured has a pulse width which is much wider than that set by the reciprocal of the video bandwidth, then the sensor efficiency values measured in pulse and those obtained from a measurement in CW are similar. This is explained for wireless applications in section 4.

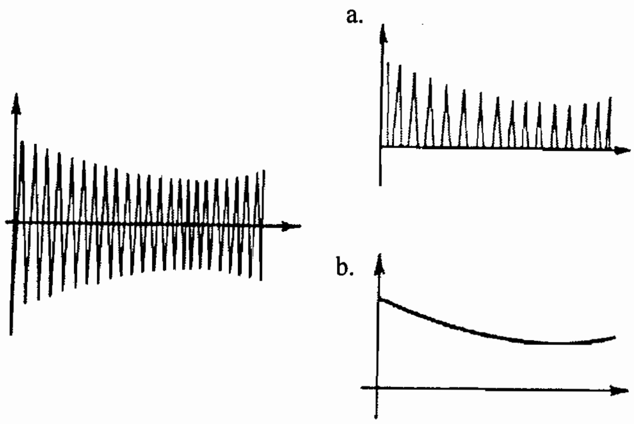

Fig.3. a) The response of a diode with a wide sensor bandwidth and
b) The response of a diode with a narrower sensor bandwidth.

Consider Fig.3 which shows an amplitude modulated CW signal. In a) the sensor has a wide video bandwidth and thus a very short rise and fall time so the signal can be accurately traced. In b) the sensor has a narrower video bandwidth so the diode responds to amplitude changes occurring at the slower frequency. In this case the diode responds to the envelope or the average power in time.

Current power measurement specifications call for the peak power and the average power in a burst to be measured. A diode sensor used to measure the peak power in the burst should have a video bandwidth wide enough to measure all power transitions relating to the symbol changes within the burst. In reality this is not practical because if for example a peak power signal was produced for a very short period then this power may not be measured correctly and an average power occurring over a time interval will be obtained. The time interval over which an average of the peak power is measured will be a function of the sensor bandwidth and must be determined for a sensor. In fact where peak power measurements are required the time interval over which peak power is to be measured must be clearly defined as it is impossible to measure instantaneous peak power. It may be stated that the sensor bandwidth must be at least larger than the highest modulation frequency. A diode sensor used to measure the average power in a burst may have a smaller video bandwidth within certain limits as described in section 2.

4.1 GSM

GSM employs the theoretically constant amplitude modulation scheme, 0.3GMSK (**G**aussian **M**inimum **S**hift **K**eying). However amplitude modulation may be introduced for example by filters or amplifiers. These changes in amplitude will occur at the symbol rate, i.e. approximately every 3.69μs, or with a frequency of approximately 280kHz but may be of very short duration. If the sensor's rise time is not short enough to seen these 'glitches' then an average will be measured. Therefore the sensor bandwidth should be at least larger than 280kHz in order to measure peak power in a burst. To measure average power the sensor video bandwidth can be less than this but must be larger than 36kHz or 1/28μs, where 28μs is defined in the GSM specification as the limit on the rise time of the pulse in the TDMA frame.

4.2 TETRA

TETRA uses the modulation technique π/4QPSK (**Q**uadrature **P**hase **S**hift **K**eying) which although should be a constant power technique (i.e. the length of the vector on the IQ diagram is constant) power deviations can occur between symbol changes. These symbol transitions occur every 56μs. Hence the video bandwidth of a diode sensor must be much larger than 18kHz in order to track any power changes.

4.3 W-CDMA

Symbol changes in the proposed third generation systems such as W-CDMA are expected to occur at a rate of 1 every 0.5μs. Therefore the sensor video bandwidth must be larger than 20MHz to measure peak power associated with symbol transitions.

5. The Measurement System

The proposed measurement system that will provide traceability for pulse power sensors used in the operating systems GSM, TETRA and DECT will be based on the comparison power measurement method [3]. Traceability will be provided through the NPL primary CW power standards.

A number of different measurement techniques are currently being evaluated and the method used to provide a measurement service will be the one that is adaptable to different modulation techniques, has the ability to extend its frequency range and produces the lowest measurement uncertainties.

A traceability route for the proposed third generation systems such as W-CDMA and the combination of TDMA and CDMA will be investigated when the specifications for these systems have been confirmed.

6. Conclusions

The power traceability requirements of the wireless communications industry are varied. The measurement service will provide traceability for power sensors used as pulse power detectors for measuring GSM, TETRA and DECT pulses with consideration being given to third generation systems. The power ranges covered will be -70dBm to +46dBm although calibrations may be done at a nominal power level and frequencies up to 18 GHz will be investigated. The measurement service will be capable of measuring peak power in adjacent pulses with pulse widths greater than 20μs. An initial estimation of measurement uncertainty for the calibration factor of sensors used to measure peak power will be less than 3% at the one standard deviation level. This uncertainty will largely depend on the uncertainty in the characterisation of specific components in the measurement system.

A second meeting with industry is planned for six months time to update and discuss recent developments.

7. Acknowledgements

This work is supported by the DTI's National Measurement System Policy Unit 1997-2000 Programme on Electrical Metrology.

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