

# On the utilisation of Millimeter Microwaves for Strip Velocity Measurements. By David Coffey 5-Sep-2006

## *The High Level Requirement,*

***Increasing competitive pressures in the steel industry, for cost reduction and more effective utilisation of plant and capital equipment, have led to a requirement for accurate and robust measurement, of key process variables at various process stages during the manufacture of rolled steel. Parameters such as strip velocity, total integrated strip length and strip thickness, increasingly need to be measured in real time and integrated into existing process controllers/PLCs in order to optimise production processes.***

## *The Status Quo,*

A number of high tech solutions, have sought applications in the steel industry to the measurement requirements stated above. These include the use of HeNe (Helium Neon) Lasers for velocity and strip length measurement and X-ray units for direct strip thickness measurement. While these products have in certain ways, gone a long way toward addressing the industry requirements, certain issues, involving the practicality of their application - in harsh industrial environments, continually pose challenges to process and instrumentation engineers at large.

## *The Challenge,*

To create a measurement platform, which adequately addresses the measurement requirements of the industry, yet addresses both the technical and business related constraints imposed by the harsh operating environment and the increasing pressure for cost reduction and better capital utilisation, together with the objective to justify capital expenditure based on TCO (Total Cost of Ownership) principles.

## *The Solution.*

Inventors throughout history have exemplified the principle that solutions to problems can often come from the least expected places.

Even if you have never suffered the indignity of having been caught speeding, you are no doubt aware, that countless hundreds of thousands of road kilometres world-wide, are covered by stationary speed cameras and mobile highway and air patrols, that can measure a vehicle's speed based on Doppler Radar principles.



Indeed, this technology is so ubiquitous and robustly implemented that its results are used in countless prosecutions. So much so in fact, that this evidence in the vast majority of cases is irrefutable to the extent that prosecution is automatic.

I.L.S. aircraft guidance systems, again utilising similar principles at the basic level, are capable of automatically landing aircraft containing hundreds of passengers and priceless cargo.

### ***The Principle.***

Speed cameras operate typically in the low to mid (X, Ka and Ku) radar bands. In order to utilise the Doppler Effect they need oblique (ideally perpendicular) incidence on the target.

Certain experimental bands have been allocated for ISM (Industrial, Scientific and Medical) and Automotive Band use and are utilised for various purposes. One such example being vehicle collision avoidance systems.

Of particular interest, is one region near 77GHz(Automotive Band,  $7.7 \times 10^{10}$  Hz). At this frequency, the wavelength is so small (<4mm) that quasi-optical principles apply and indeed the radar beam can be focused with small, inexpensive lenses just like conventional optical instruments.

One effect, which becomes apparent at these low wavelengths, is that when the wavelength of the incident beam approaches the geometric dimensions of the illuminated target, diffraction artifacts become significant.

More specifically, these diffraction effects create back-scattering centres that enhance the interference between the transmitted and reflected electromagnetic waves thus increasing the effective R.C.S. (Radar Cross Section) of the target.

Ultimately, this means that Doppler information can be extracted efficiently from a moving strip using a novel 'edge illumination' technique.

### ***The Benefits,***

Doppler measurement methods utilising this edge illumination technique, are not dependant on the medium reflectivity and are thus immune to reflectivity variations which compromise the dynamic range of purely optically based Doppler interferometers.



The Doppler 'beat frequencies' generated by this method can be directly measured using conventional spectral estimation techniques such as F.F.T. (Fast Fourier Transform) methods and do not rely on expensive and elaborate fringe counting techniques required by optical interferometers.

Radar beams, by comparison, are far more impervious to environmental factors such as attenuation by water and oil mist and indeed dust and solid particle debris, which can totally occlude a laser beam.

Another significant consequence of this approach is that the edge illumination technique lends itself particularly well to hot rolling environments. Traditionally, lasers need to be mounted directly above the strip and require cost intensive thermal protection and cooling systems.

### ***The Product,***

Doppler Radar Velocimeter 'Vel 1', is a product which uniquely addresses the requirements of the steel industry for a cost effective measurement platform while rising to the challenges posed by conventional industry measurement techniques.

The system is fully self contained, is capable of operating in a standalone fashion over the industry standard 4-20mA current loop and can output instantaneous strip velocity or integrated strip length at a refresh rate of up to 15 times per second together with diagnostic fault levels. In addition the unit contains two relays which can be set to trip at user defined over and under levels

Units can be combined in differential mode at various stages along the mill and by directly measuring the mill velocity gradient can provide volumetric and thickness gradient measurements potentially replacing expensive and space consuming x-ray units.

Specifically, within the rolled steel industry, the unit can be installed inobtrusively in hot and cold rolling mills, pickling lines and backrolling stations.

A digital diagnostic interface via a standard serial communication port can place the unit under direct control of a computer terminal. The unit has extensive logging memory and can store and export velocity and length profiles to industry standard data analysis packages seamlessly.

The complementary host program 'Velterm' can control, diagnose and export velocimeter data for graphical analysis and tabular data analysis using Microsoft™ Excel.



The unit is enclosed in an 'Adalet' industrial enclosure which offers environmental protection similar to Nema 4 and has Class I group B,C,D, Class II group E,F,G, class III type 4X, class I zone 1A Ex IIC, Exd IIC IEC 60529 IP66 approvals. The cable port is via a ¾" NPT conduit entry.



Figure 1. Vel 1 Shown here on a US Letter sized sheet of paper for perspective.

