Project No.
COOP-CT-2005-016927

Project acronym
WAVESHIFT

Project title
THE DEVELOPMENT OF A NOVEL INTEGRATED SUPER HIGH FREQUENCY (SHF) NON CONTACT UNIT FOR MOBILITY DETECTION AND SPEED MEASUREMENT

Instrument: Co-operative research projects

Thematic priority: Horizontal Research Activities Involving SMEs

PUBLISHABLE FINAL ACTIVITY REPORT

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Project coordinator name: John Hallatt
Project coordinator organisation name: Microwave Solutions Limited | Revision: 1

Section 1 – Project execution

1.1. A summary description of project objectives

The Scientific Objective of the work has been to advance the knowledge of characteristics and performance of microwave transceivers operating at Super High Frequencies (with the focus on the 24GHz ISM band) using low cost microwave materials.

The Technological Objective of our work was to develop a low cost non contact universal microwave Doppler unit capable of detecting motion and direction of movement, measuring speed and allowing for estimation of the size and type (material) of moving objects. The key policy driver relating to harmonisation of systems across the EU is R&TTE Directive 1999/5/EC referencing the Harmonised Standard EN 300 440. Also of special importance is ERC Recommendation 70-03 (May 2007) Annexes 1 & 6, specifying the recommended frequency ranges for short range devices. Primary Directives for electrical products are the Electro-Magnetic Compatibility (EMC) Directive and Low Voltage Directive. Electrical EN standards are issued by the EU sponsored organisations ETSI and CENELEC (Comm. Eur. Norm. Electrotech). Also CE Mark and ENEC Mark[1].
Our detailed technological objectives pertinent to the development of a non contact microwave Doppler unit consisting of microwave electronic components and circuitry, a planar integrated antenna and EM shield/protective housing have been:

- To allow for the detection of objects of the size (> 1 m height) and weight (> 45 kg) of a human adult at a distance of up to 30 metres moving with a speed between 0.03 and 1.5 m/s (OBJECTIVE MET).
- To provide a coverage angle of 72 degrees in azimuth and 36 degrees in elevation for security applications. For the application in automatic door openers allow for selecting the coverage pattern to the following configurations: 36 x 72, 72 x 36, 18 x 72 or 72 x 18 degrees (OBJECTIVE MET).
- To allow for operation at ambient temperatures between -30 C and +85 deg C. whilst ensuring that frequency stability versus temperature will not be worse than ±0.5 MHz/deg C (OBJECTIVE MET).
- To ensure the European Harmonised Standard requirements for spurious and harmonic emission levels are met: spurious emission (max) EIRP = - 42 dBm, harmonic emissions (max) EIRP = -32 dBm (to 4th harmonic). Spurious and harmonic specifications measured above 1 GHz and assume 11 dBi gain antenna (OBJECTIVE MET).
- To allow for significant decrease in size in comparison with currently available units. The target dimensions including housing are 35x25x10 mm (OBJECTIVE MET).
- To ensure the current consumption is not higher than 40 mA in continuous operation (OBJECTIVE MET).
- To allow for power supply of 5 ±0.5 V (OBJECTIVE MET).
- To allow easy integration with other types of sensors within dual technology solutions including PIR (OBJECTIVE MET).
- To achieve a manufacturing cost base of the integrated motion detector unit of €3 or less. The motion detector unit will be a building block for manufacturing motion detection and speed measurement sensor systems (OBJECTIVE MET).
- To achieve a 10 year minimum design life (OBJECTIVE MET – proved by simulations and calculations).

1.2. Contractors involved in the project

SME PARTNER 1 MSL

[1] Chartered Institution of Building Service Engineers Fact file No.4 Nov 1996

Microwave Solutions Ltd (MSL) is a UK based SME. MSL pioneered the application of planar antenna technology to low cost motion sensing devices. Active in this field since 1991, we have played a key role in the development of reliable dual technology intruder alarm sensors for the security industry. More recently our products have been applied to a wide range of other industries, including automotive sensing, short range communications, range sensing etc. Our core capability is in design, manufacture, sale and support of a full range of X-Band (10GHz) microwave doppler motion detector units. Our units are available as a "transmit only" version, with a single mixer or with a pair of orthogonal mixers for direction sensing applications. Through our links to sister companies within the SME Secure Holdings Group who are the market leader providing sensors for security systems MSL offers a direct route to end users. MSL is an active member of the LPRA (Low Power Radio Association).

Role in the Project
MSL was the coordinator for the project and lead WP8 and WP9. MSL was responsible for the integration of the unit as the key components were developed. MSL's ability to deliver customised microwave Doppler units for different applications makes MSL an important and attractive partner within the consortium. Excellent understanding of customer needs and the background knowledge on delivering detector units in large volumes while ensuring low prices, international sales and marketing presence enables maximum exploitation of the developed technology. The main contribution to the work was in the areas of background technology appreciation in the core industry sector within various WPs and the input to integration process undertaken within WP5.

SME PARTNER 2 Cube

Nature of Business
Cube is a Czech SME established in 1999 to continue and develop a long tradition of printed circuit manufacture in the locality of Jizerske Mountains (north Czech Republic). They specialise in production of technologically demanding printed circuits while maintaining the highest quality standards. Their mainstay is prototype to medium runs in express delivery service. Their quality has been confirmed with numerous certifications e.g. Underwriters Laboratories and ISO 9002. Their technological capabilities cover production of single-sided, double-sided and multilayer (up to 16 layers) PCBs. Cube provides services ranging from PCB design and development, through PCB assembly, to microsections and solder paste stencils. Cube were second in national competition for "The 'Subcontractor of the Year" Certificate by the Czech government agency CzechInvest.

Role in the Project
Within the project the activities carried out by Cube were in a number of WPs. However, their key role was the input to the development and manufacture of a prototype multilayer PCB as one of the key components of the WaveShift unit (Task 5.1 in WP5). They ensured that the technology was fully compatible with standard PCB manufacturing process to ensure low production costs. Within this process Cube actively cooperated with Schaal who provided the guidelines on the shield implementation. This was essential to ensure that all the board related parameters which influence on the microwave unit performance were carefully investigated through the manufacturing process.

SME PARTNER 3 Schaal

Nature of Business
Schaal is a German SME founded in 1874 who has further developed their core business of metal surface finishing. Since 1960 surface finishing for plastics has been an integral part of their spectrum of services. With just under 250 highly qualified employees, a modern equipment fleet, many years of experience in surface finishing and manufacturing in accordance with national and international quality standards, they are now one of the leading suppliers of specialised surface finishes and plastic components. They provide top quality decorative and functional surfaces for products with electroplating and painting using state-of-the-art technologies. The electroplating can be made by Schaal with copper, nickel, chrome, blue and yellow zinc (rack and barrel plating processes), black zinc (rack plating process), and chemical zinc plating. The painting process can be applied to create protective and decorative paints on titanium, magnesium and aluminium. Schaal provides similar processing of plastic components which can be subject to chrome plating, painting and chemical metallisation.

Role in the Project

Schaal brought combined capabilities for producing injection moulded plastic parts and producing shielding through metallisation on plastics necessary for the project. These skills did not exist elsewhere in the partnership and complement the other skills of the industrial partners. They metallised plastic housing for the microwave unit which on one hand increased interference immunity and decreased interference emission but also contributed to ensuring thermal stability of the unit. Therefore, their key role was in WP 4.

SME PARTNER 4 Linwave

Nature of Business
Linwave Technology is a UK based RF and microwave SME company with specialist knowledge in module and sub-system design. Their experience encompasses the consumer, industrial, automotive and defence markets. The Linwave design team is highly qualified with the experienced professional staff having in excess of 100 man years design experience in microwave, wireless communications, military, commercial and automotive market sectors. Today Linwave employees are involved in different projects providing solutions and tailor-made systems for wireless radio applications. This includes both hardware and software engineering. The highlights of this process are integrated systems on a chip (SOC), customised antenna designs and high-accuracy component modelling, as well as electromagnetic compatibility. They also have the complete capability in-house to produce quantities from fully compliant prototypes through to full production. In house design and test capability extends to 50GHz.

Role in the Project
Having previously been involved in the development of Doppler radar systems for different applications Linwave was a valuable partner to our project. We benefited from their background IPR in the WaveShift project. Linwave was primarily involved in the design and development of the prototype of a microstrip antenna as well as its testing.

SME PARTNER 5 RCD

Nature of Business
RCD spol. s r.o. are a Czech SME established in 1993 who deliver various types of antennas and filters. They employ 70 people, with annual turnover of 85 million Czech Crowns. Today RCD specialises in the development and supply of antennas for all professional bands from 80 MHz to several GHz. They manufacture directional, collinear and panel antennas including antennas in a fibreglass radome for protection from ambient weather conditions. Apart from antenna systems RCD develops and supplies duplexers, filters, amplifiers, repeaters and connectors. The company production workshops are equipped with basic equipment for mechanical metal processing while electro-assembly workshops have SMT circuits assembly capabilities. RCD has supplied antenna systems and radio repeaters to Czech Police, special antennas to Czech Army, measuring antennas for Czech Telecommunication Authority.

Role in the Project
RCD actively participated to several WPs. However, their key role was to bring the input to the development of the microstrip antenna and associated circuits within WP2 which they led. They also utilised their skills in testing of the developed antenna to confirm that it meets the requirements identified within the scientific characterisation of the requirements for the microwave unit. Their ability to innovate, previously recognised by large customers in their domestic marker, made them an important and attractive partner within the consortium.

SME PARTNER 6 S.M.A.

Nature of Business
S.M.A Sp. z o.o. is a Polish SME, located and operating in the local Polish market. Established in 1992, they were the first professional provider of alarm monitoring services in Poland. S.M.A. operate under the licence assigned by the Polish Ministry of Interior and Administration. When providing their services, they follow the procedures required by their ISO 9001 certification. The company is active in selling, installing and maintaining electronic

equipment in security systems for control and supervision, and monitoring. At the moment S.M.A provide their services to residential subjects and apartments, banks, museums, churches, jewelleries, warehouses, car parks, retailers, offices, and production plants,. Presently S.M.A. monitors over 5000 alarms installations in Warsaw, Wroclaw and surrounding areas.

Role in the Project
S.M.A initially advised on existing used sensors based on their experiences collected over the last 12 years. They advised on the required functionality and technical characteristics of the detector unit in WP1. S.M.A. brought an excellent opportunity to validate the developed unit in security applications. They evaluated the unit from the perspective of the target end user. A benefit of S.M.A evaluating the unit was that they could validate the detector unit in a real environment. S.M.A. have business contacts within other towns in Poland and therefore can direct and access the scope of the skills set changes and knowledge transfers needed for similar SMEs to be developed in the current market. S.M.A. was therefore active in the WP 6.

OTH PARTNER 7 Besam

Nature of Business
Besam Group is a large organisation based in Landskrona, Sweden, who operate in the global market of automatic doors for pedestrians and employs over 1400 people. Although their main assembly/distribution facility is located in Sweden, Besam has facilities for assembly and door manufacturing also in Germany, Dieburg and USA. Today Besam is present in 22 countries over the world with fully owned sales companies and represented in many more countries by independent distributors. Besam is active in developing, manufacturing, distributing and servicing different types of automatic doors. The core products are automatic operators for sliding doors and swing doors, often delivered integrated in a full entrance system. In addition Besam offers a range of revolving doors. All systems include automatic operators containing, motors with control, mechanical structure to carry and/or power the doors and sensors for automatic opening and safety.

Role in the Project
Besam represents end implementation of the technology in the secondary application which is the sensor for automatic door opener. They evaluated the customised unit by integrating it within their system for steering the door. A clear benefit of Besam evaluating the system was related to the fact that they are the market leader in the sector so they could provide an excellent route for the exploitation of the WaveShift unit for the benefit of all projects participants. Besam was particularly active in WP5 Assembly& Integration and WP6 (Motion Detector Validation).

In order to achieve this concept, and lacking sufficient research capability of their own, the SMEs sourced two RTD providers with a deep understanding of, and the capability to provide a unique technology step change solution to the problem.

Research and Technology Developers (RTDs)

PARTNER 8 InnowacjaPolska

Business Activities

InnowacjaPolska is a leading independent high technology research organisation in Central and Eastern Europe, with a highly respected international client base. They provide research and technology development services for the design and development of customised software for industrial applications and high level electro-mechanical design, development and installation. They have experience in the design and development of sophisticated wireless systems for acquisition of data from remote sensors using different transmission protocols. Their expertise includes also the development of solutions for storage and processing of multidimensional data, network system development and integration. InnowacjaPolska operates within a non-profit distributing corporate structure with an objective to generate and transfer new technology to industry, providing step change improvement in competitive advantage for industry as a whole.

Why Selected?

InnowacjaPolska has important skills in electronics engineering and have direct expertise in the areas of development of electronic sensor and special purpose electronics incorporating intelligence. This experience includes deep knowledge of the use of various microwave electronic components and appropriate design methods. InnowacjaPolska have successfully completed a number of relevant projects, such as Vibcon – remote data acquisition for remote monitoring and control, through the application of the similar skills that will be required in this project including wireless sensor development. The skills of the key technical staff cover all the aspects related to the research in the field of designing optimal microstrip antenna layout and leads, selecting proper electronic components, designing microwave electronics and circuits, ensuring temperature stability of super high frequency electronics and digital signal processing. The project will enlarge for them the geographic span of their activities developed through the partnerships with the industrial partners as well as science and research institutions of the project. Through participation in this project, InnowacjaPolska has benefitted by getting new knowledge in the field of shielding with plastics finished with metals and enlarged their expertise in the design of microwave devices

Partner 9 CRIF

Business Activities

CRIF is one of the most important technological research centres in Belgium. They have 2450 company members, representing the following sectors: metals and polymers processing, mechanics and mechatronics, automotive and transport, electricity and electronics, information and communication technologies. More specifically, Liege's department which has been involved to the WaveShift project participates to European projects aiming to develop and transfer knowledge in different fields like rapid manufacturing, moulding of light materials in semi-solid phase, or processing of nano-materials. Other actions are initiated in the field of packaging and traceability of products. CRIF has developed skills in the field of light conductive materials used in new products fulfilling electromagnetic compatibility criteria. The knowledge built at CRIF is related to electrically (and thermally) conductive polymers and also metal matrix composites. Besides this, CRIF is active in several European projects in the field of carbon nanotubes and their use in conductive materials. By today CRIF have been active in many European projects (BRITE, CRAFT, LEONARDO, ADAPT, Interreg,) and is currently involved within the 6th Framework Program, in 3 Integrated Projects and 2 Collective Projects.

Why Selected?

CRIF possess considerable experience in selecting material for the shielding applications that meet the EMC requirements. The methodologies they develop can be used to precisely match the type of plastics and metallisation layer while advising on the method for metal surface finishing. Their material engineering skills has been valuable in selecting materials which, apart from ensuring the EMC performance, will provide significant input to the thermal stability of shielded electronics. Specifically, the competence of their research staff in simulating injection moulding and modelling of thermal exchange phenomena has made them a valuable partner to play the role of an RTD in our project.

Complementarity Between Participants

The consortium consists of 6 specific SME Core proposers from 4 EU member states (Czech Republik, Germany, Poland and UK) and a large company (Sweden). The SME Core proposers were primarily involved as a potential start-up supply-chain while the large company represents one of the end user communities implementing the developed Doppler sensor in their products. Whilst the Core Group are highly innovative and able to create the novel detector unit within the project and identify they need new enabling technology to realise their need as they have very limited research capability. Therefore, two RTD Performers have been engaged to provide the deeper S&T skills and expertise in the area of microwave circuit modeling and antenna system design, RF isolating materials to ensure required EMC, thermal stability for electronic circuits and transceiver development. These skills helped the Core Group to realise their innovative ideas by overcoming the development risks. The proposers have come together to provide a good balance of complimentary skills, which has facilitated the

transfer of knowledge to assist and concentrate work activities and achieve the project objectives. The Core group of SME's were active in many of the Work Packages, and dissemination and exploitation tasks. They played an important role in the management aspects and helped to establish the initial routes for the technology into the market. The structure of the Group of Participants was such that it clearly formed the basis for non conflicting - commercial supply chains providing the technological solution to the target end users represented by S.M.A and Besam, capable of forming a suitable vehicle for post project development, marketing and product support. MSL has extensive experience in assembling different versions of microwave Doppler units operating at 10 GHz. They provide necessary capabilities and knowledge of mass production techniques as well as deep understanding of market needs. Cube provides skills in the area of manufacturing of non standard multilayer PCB capable of integrating different components. Schaal brings skills and production capabilities in metal surface finishing and plastic components. Linwave brings much needed expertise in the field of characterisation and testing of microwave circuits and antennas along with background IPR. RCD as a manufacturer of antenna systems provides capabilities in manufacturing of customised antennas of different architecture and for different applications. S.M.A brings their experience in supervision and monitoring of complex alarm installation in commercial and residential environments. Besam, as a large manufacturer of automatic door openers, provides the opportunity to validate the developed unit in this specific application.

The RTD proposers carried-out complementary and non-duplicating work activities, using suitably qualified researchers.

1.3. Work performed and end results including the description of methodologies and approaches employed

Our first objective was to scientifically characterise and determine the optimum parameters for the short range motion and movement direction detection unit, exploring methodologies for enhancing detection accuracy in a variety of environments and ensuring resolution capabilities to enable the full characterisation of a commercially viable detector. These results were published in the Deliverable D02: *Report on: the theoretical analysis of microwave motion detectors, requirements & functionality, specification of proposed architecture and risk assessment.* On the basis of this document the RTD performer Innowacja Polska (InnPol) together with SMEs: Microwave Solutions Limited (MSL) and Linwave Technology Limited (Linwave) developed another document named *Motion Detector Unit Specification Review*. This contains practical, experience based instructions and comments on possible problems that may occur and ideas of how we can avoid difficulties.

The next goal was to define the substrate for the Printed Circuit Board and on the basis of it, design and build microstrip antennas meeting the requirements defined in the theoretical, technological review. We have chosen the substrate to be Rogers 4003 according to the *Motion Detector Unit Specification Review*. RO4003 is available in 0.2mm and 0.5mm thickness, the dielectric constant is nominally 3.38 and the loss tangent is 0.0027 at 10GHz. The coefficient of thermal expansion and temperature coefficient of ε_r are good for this type of material and meet the required specification. RO4003 can be processed using normal, commercially available FR4 high volume circuit processing techniques without the need for specialised processing steps. The material is suitable for high volume assembly using pick and place machines. Then we continued with the development of a beam switching mechanism based on a novel PIN diode switching model. The prototype was designed and tested. The proposed reconfigurable antenna array has been developed. As radiating elements, square patches directly fed by transmission lines have been used. In order to minimize the losses within the feed network the patches have been placed so that the input ports face each other. Such an arrangement requires an additional 180° phase shift between the signals feeding the two radiating elements. The 180° phase shift has been achieved by adding a meander-line section of transmission line. Additionally, in order to minimize radiation from the feed network the radiating elements have been designed with an 85 Ω impedance. Matching the antenna array input to 50 Ω is then achieved using a single-section 90° impedance transformer at the antenna array input. Below there is a photo of the prototype PCB. Results of the development were published in the deliverable D03: *Developed prototype of the modular microstrip switched antenna*.

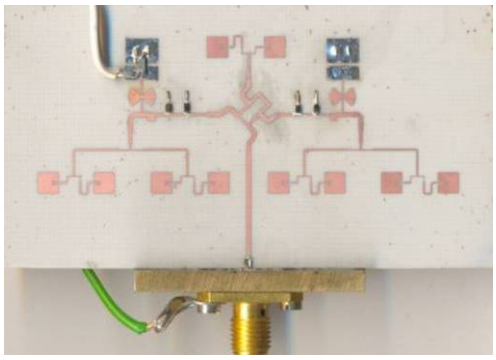


Figure 1. Prototype of reconfigurable antenna.

The next objective was to develop a multi layered Printed Circuit Board in which the antenna system constitutes the whole of one side and the other side is used to accomodate the microwave electronics. A groundplane layer was buried within the Printed Circuit Board. Our next aim was to design and build the separate microwave elements of the detector: 24GHz oscillator power splitter and microwave mixer. To design the active microwave elements we applied microstrip technology with passive elements made in the form of transmission lines and with surface mounted active components. RO4003 was again used as the substrate. For the active component in the oscillator we used an N-channel Field Effect Transistor (FET). We have developed two versions of the oscillator as depicted in Figure 2 and Figure 3 respectively.

Figure 2: First prototype of oscillator

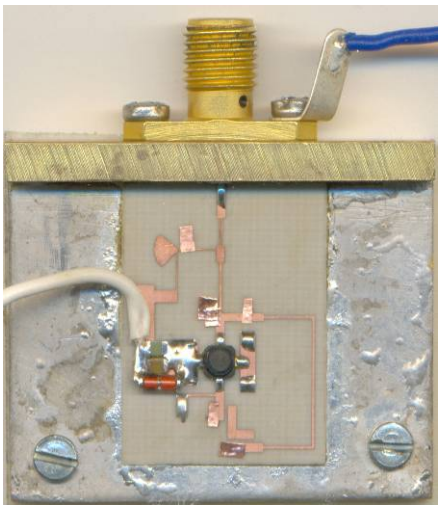


Figure 3: Optimised version of oscillator

The most important parameter of the oscillator's performance is its thermal stability. This means that over the required range of temperatures, the oscillator generates the desired frequency in a stable manner. A detailed study of the prototype oscillator and single radiant elements was performed and issued in the form of Deliverable D07: *Report on thermal stability*. Figure 4 shows the resonant frequency graph as a function of the ambient temperature.

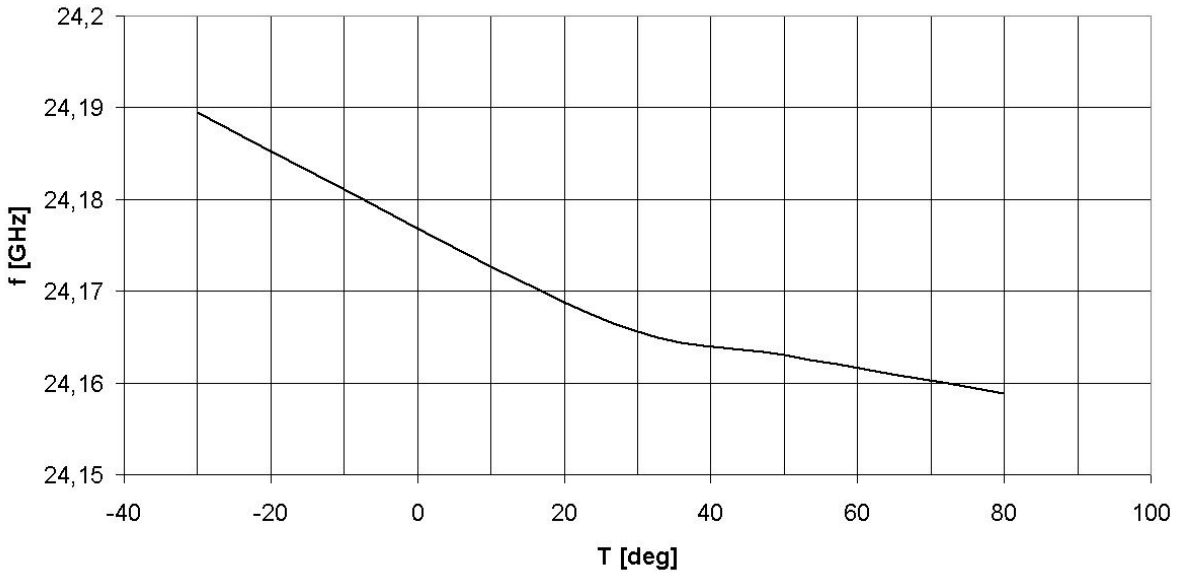


Figure 4: Resonant frequency of oscillator as a function of temperature

It is noticeable that there is a 30 MHz reduction in resonant frequency over 110^0C, which corresponds to approximately 0,3 MHz drop per 1^0C. This is a better result than declared in the state-of-the-art where we defined the thermal stability would not be worse than 0.5 MHz/^{0}C although it does not take into account the potential adverse effect of the EM Shield or housing.

The next objective was to design and build the microwave mixer. Having investigated the possible technologies, we have decided that we would design two types of mixers, an active mixer based on a Field Effect Transistor (FET) and a passive mixer based on single ended and single balanced Shottky diode mixers.

Prototypes of the mixers are depicted on Figure 5, 6 and 7:

Figure 5: FET based microwave mixer

Figure 6: Single ended diode mixer

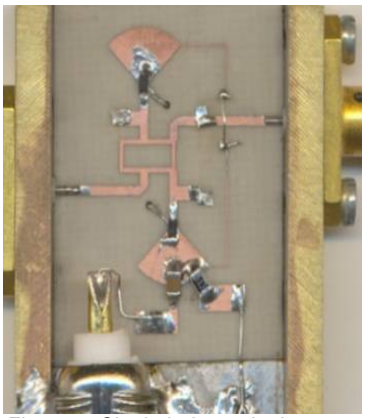


Figure 7: Single balanced mixer

After the development of independent modules we selected the optimal configuration of them and developed an integrated design. Figure below depicts complete and integrated PCB.

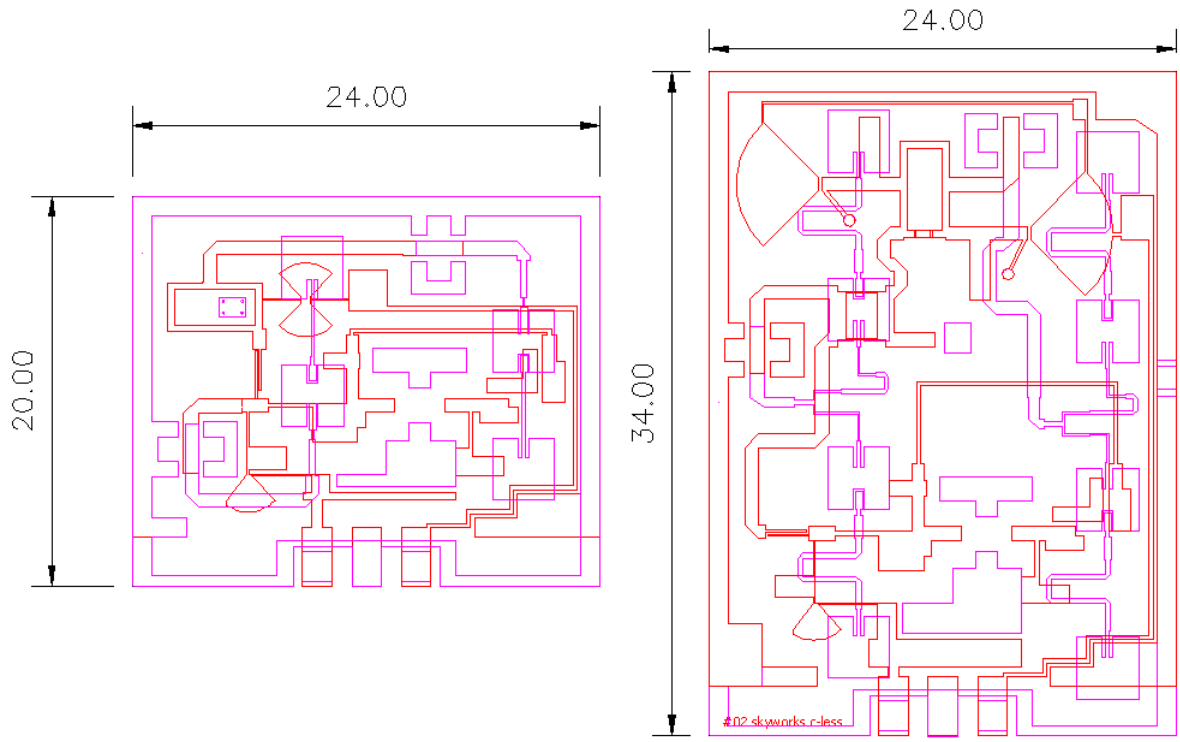


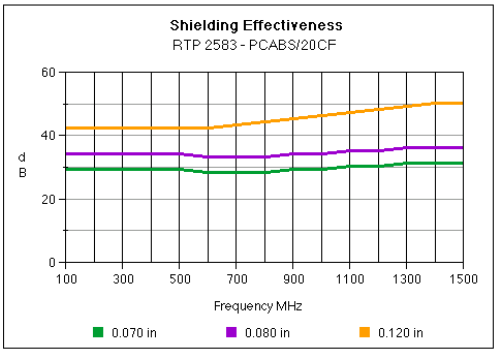
Figure 2. Design of compact Doppler sensors with a 2x1 antenna array (left) and 4x1 antenna array (right).

The next goal was to evaluate different system configurations, followed by bench testing to confirm radiation pattern characteristics against reference designs (e.g. based on a waveguide horn). In all cases the antenna arrays that were developed exhibited good return loss characteristics within the operational band. Measured gains were 3-4dB below the calculated values for the corporate fed-antennas and about 2dB below the calculated values for the series fed antennas. This is a reflection of the resistive loss of the substrate material used and the detrimental effects of radiation from the feed. Measured radiation patterns were in good agreement with predictions. All antennas have -3dB beamwidths of approximately 36° and 18° for 2x1 and 4x1 arrays respectively in one plane. In the orthogonal plane both antenna configurations have a -3dB beamwidth approximately equal to 72°. The antenna arrays with series-fed corner-fed patches have greater beamwidth in the orthogonal plane - equal to approximately 130°. Overall the measured parameters for the developed antenna arrays for the 24 GHz motion detection sensor are consistent with the specification and therefore the antennas are suitable for use in the application.

The next part of work we have conducted was the development of a thermally improved prototype housing. This housing was designed to achieve a number of criteria to ensure that the motion and direction sensor was thermally stable while ensuring the required shielding parameters were met. We have studied several different possible manufacturing techniques for the housing. The main categories of materials that can be used for the housing are plastic or metallic materials. Plastic material alone does not provide the necessary electromagnetic shielding so post-processing is required. The additional process in this situation was metal plating of the housing. Manufacturing the housing from metallic materials is a novel and innovative approach. We also carried out studies on the thermal conductivity. It was discovered that there is no difference in the thermal conductivity between plastic materials with and without stainless steel fibres. After the first reporting period (P1) we defined the key parameters for domestic and harsh outdoor environment (see description of Task 4.1. in P1). We continued to investigate different materials, fillers and coating to manufacture the housing. An existing housing geometry was selected to perform the shielding tests and the thermal stability tests with an existing sensor. A prototype mould was built to inject different kind of materials (ABS, glass fibre reinforced PA6 and PC) with and without conductive fillers (stainless steel fibres) for the EM shielding properties. Some of these prototypes were coated with a conductive layer. Different kinds of coating were tested (electroplating of Cu-Ni, Physical Vapour Deposition of Al and conductive painting). Furthermore, two metallic prototypes were machined from Aluminium

(Al) and Magnesium (Mg) blanks. The EM shielding properties and the evaluation of the thermal stability of all these housings were carried out by MSL. A prototype mould was built to inject several thermoplastic materials. The selected materials for testing are given on the following table. Some of these materials were combined with conductive fillers (stainless steel fibres) and/or a conductive coating.

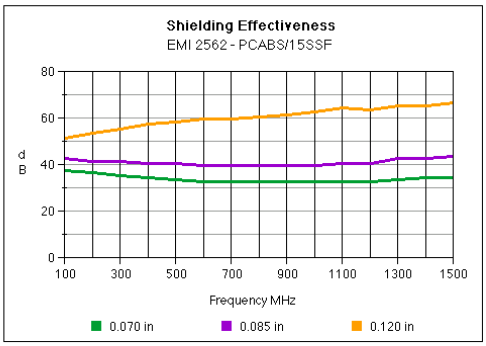
The EM shielding properties of a housing are difficult to predict because they depend on a variety of parameters such as operating frequency, the nature of the emitting source, the housing material, the wall thickness and the geometry. In our case (near field, small distance from the source), we have a high wave impedance (electric field higher than magnetic field). For this reason, we decided to test the effect of conductive fillers in the housing material. We selected three different grades of stainless steel fibres from Bekaert (BEKISHIELD GR75 C12, C16 and C20) and different content levels (10% and 15% weight percentage). In parallel, surface shielding was also investigated using different techniques (Physical Vapour Deposition of aluminium, electroplating of Cu-Ni and conductive painting).
Two metallic prototypes of the housing were made in aluminium and in magnesium. The shielding properties are shown on the next pictures.



Carbon Fiber

- Reinforcing
- Highest strength/modulus properties of the common shielding additives
- Lowest cost of the common shielding additives
- Low shielding performance

View Product Data Sheet

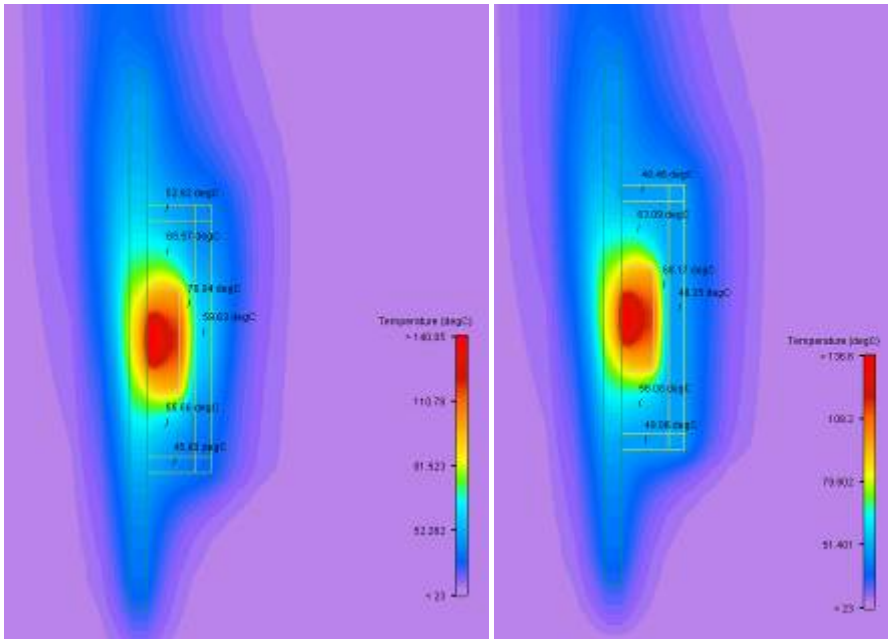


Stainless Steel Fiber

- Non-reinforcing
- Minmal effect on neat resin properties
- Similar mold shrinkage to neat resin
- Good shielding-to-cost performance
- Best colorability of the common shielding additives

View Product Data Sheet

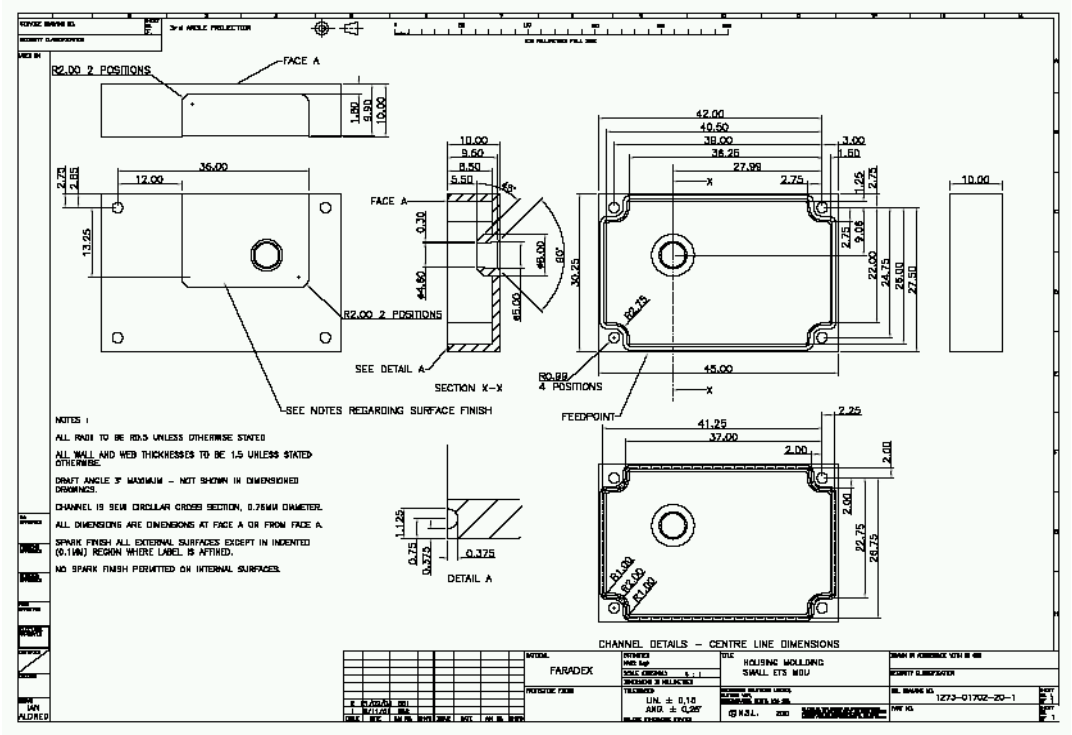
To establish the thermal stability of the housing, a thermal simulation was performed with an inner power of 1W. The thermal results are shown below.



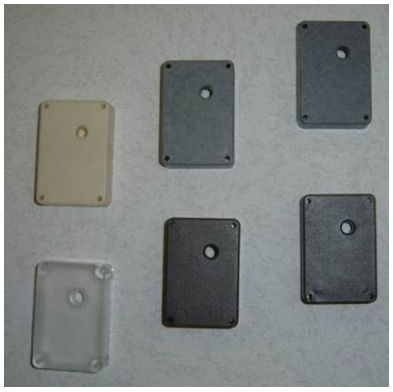
Thermoplastics housing (1W in – 1.5 mm thick) Mg housing (1W in – 1.5 mm in)

The inner air temperature reaches 55 °C to 80 °C. The temperature of the plastic housing was between 45°C and 60 °C. The thermal gradients in the Mg are much lower with temperatures between 48°C and 48.5 °C. In these conditions, the maximal deformation of the plastic housing is 0.09 mm and 0.03 mm for the Mg. These deformations are both very low.

Another task objective was to design the prototype housing and prepare tooling for injection moulding. The geometry of this housing is shown on the next picture.



A prototype mould was built and used for the injection moulding of trial series. The prototypes were tested by MSL to evaluate the EM shielding. Plastic prototypes (PC and ABS with and without stainless steel fibres) and Mg prototypes are shown on the next picture.



After successful completion of the development of all independent elements of the detector we moved to WP5: Integration and testing. The main goal was to develop a working prototype of the motion and direction sensor and to benchmark its parameters. We began by manufacturing a multilayer board with chips. All the partners involved in this part of the project put effort into successful production of different variants of the multilayer board integrated with antenna. After PCB production the circuit boards were assembled by hand and a variety of tests

were performed to establish the integrity of the circuit design. Here are exemplary photos of validated prototypes of different modules for motion and direction sensor module.

Figure 3a. Multilayer Doppler sensor with a single-balanced mixer and mounted components. IF and power supply connectors. Microwave electronics side.

Figure 3b. Multilayer Doppler sensor with two single-balanced reduced-size mixers (U-shape mixers) and mounted components. The unit has direction sensing capabilities. IF and power supply connection made in inner layer. Microwave electronics side.

Next we assembled the complete motion and direction detector for security applications and automatic door openers, i.e. assembled the printed circuit with chips inside the housing. Here are exemplary photos of integrated motion and direction sensor.

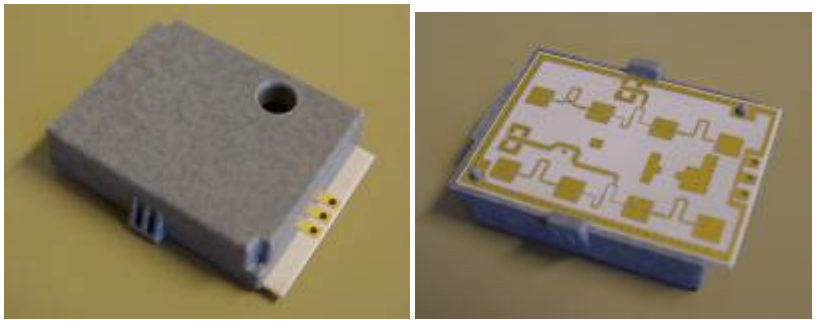
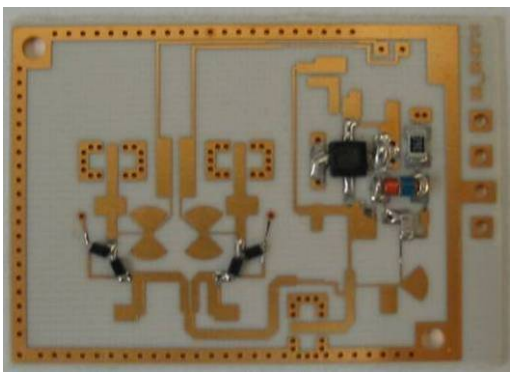


Figure 4. Integrated motion and direction sensor

Finally we performed prototype testing. Results of this testing show usable performance for the first fully functional prototype and the basic functional requirements have been demonstrated. Further iterations will refine and optimize the module performance. Results are described in details in D15: *Report on laboratory and environmental tests.*

The last technical WP in the project was devoted to the validation of the sensor in a detector. The integrated prototype was presented during meeting of month 21 to all Attendees. However several prototypes were available earlier (about month 19) to all Partners involved in validation activities. Each Partner undertook validation with a focus on his specific role. Results of the validation are described mainly in deliverable D16: *Industrial and end user validation report*. The final conclusion is that validation designs and established the functionality of the developed serious did not reveal any fundamental flaws or validation by technical or technological problems. After end-users. As the developers, detectors were validated by can be a result they declared that Waveshift™ unit In these tests, treated as a fully working movement detector. it was not because of timescale and quantity constraints, alarms possible to measure an exact percent of false installed reduction in case of using dual detectors with Waveshift™ unit but in our opinion the most important issue of introducing Waveshift™ unit into the market will be the price and quality of the PIR detector with which the Waveshift™ unit will be merged. From a theoretical



standpoint dual technology detectors are less prone to false alarms than conventional detectors. From our testing we can conclude that the Waveshift™ detector does not generate false alarms with a higher frequency than other dual technology detectors. Therefore the main obstacle to wider use of dual technology detectors in the security market, is price. If the sensors created during the Waveshift™ project can be manufactured at the price level planned in the project, S.M.A and BESAM believe that the product will be successful in a security and door-opener market.

Figure 5: SMA (monitored site)

1.4. Elaboration on the degree to which the project's objectives and goals were reached

Our detailed technological objectives pertinent to the development of a non contact microwave Doppler unit consisting of microwave electronic components and circuitry, a planar integrated antenna and EM shield/protective housing were:

- To allow for the detection of objects of the size (> 1 m height) and weight (> 45 kg) of a human adult at a distance of up to 30 meters moving with a speed between 0.03 and 1.5 m/s (OBJECTIVE MET).
- To provide a coverage angle of 72 degrees in azimuth and 36 degrees in elevation for security applications. For the application in automatic door openers allow for selecting the coverage pattern to the following configurations: 36 x 72, 72 x 36, 18 x 72 or 72 x 18 degrees (OBJECTIVE MET).
- To allow for operation at ambient temperatures between -30 C and +85 deg C. whilst ensuring that frequency stability versus temperature will not be worse than ±0.5 MHz/deg C (OBJECTIVE MET).
- To ensure the European Harmonised Standard requirements for spurious and harmonic emission levels are met: spurious emission (max) EIRP = - 42 dBm, harmonic emissions (max) EIRP = -32 dBm (to 4th harmonic). Spurious and harmonic specifications measured above 1 GHz and assume 11 dBi gain antenna (OBJECTIVE MET).
- To allow for significant decrease in size in comparison with currently available units. The target dimensions including housing are 35x25x10 mm (OBJECTIVE MET).
- To ensure the current consumption is not higher than 40 mA in continuous operation (OBJECTIVE MET).
- To allow for power supply of 5 ±0.5 V (OBJECTIVE MET).

- To allow easy integration with other types of sensors within dual technology solutions including PIR (OBJECTIVE MET).
- To achieve a manufacturing cost base of the integrated motion detector unit of €3 or less. The motion detector unit will be a building block for manufacturing motion detection and speed measurement sensor systems (OBJECTIVE MET).
- To achieve a 10 years minimum design life (OBJECTIVE MET – proved by simulations and calculations).

Conclusions:

1) During our project all technical objectives were met,
2) All project deliverables were delivered on time,
3) All WPs and Tasks were successfully completed.
4) We have completed the project with a laboratory prototype of motion detector with parameters (technical and economical) which in opinion of end-users will make a production version of this unit successful in the security and door opener markets.

1.5. The achievements of the project to the state of-the-art

The use of microwave radiation at a frequency of 24 GHz for the Doppler radar design will transcend the current state-of-the art by overcoming most of its limitations and bringing a variety of new features. The developed solution based on 24 GHz microwave radiation allows us to:

- apply for many application and market sectors (security and surveillance systems, door openers, navigation systems, the automotive market, speed and red light signal violation enforcement systems, intelligent home systems),
- improve the accuracy of the radar (up to centimetres in the case of the “free-licence” 24GHz band with 200MHz frequency deviation),
- minimise radio interference with other radar / communication systems,
- increase the ability to separate the obstacles,
- minimise electromagnetic emission (the EM compatibility) due to radiation nature.

The key advantages over currently used systems for motion detection are: wide area of applications (as one of primary objectives), low cost, high reliability and precision, thermal stability with reduced power consumption and no radio interference with other systems (short range application in licence exempt band). In order to achieve that we had to overcome the primary technical barriers. We achieved these by:

- designing the unit using low cost microwave materials, without expensive materials such as LTCC technology.
- using a microstrip antenna to assure small dimensions and portability. The microstrip antenna is designed in the form of replicable submodules which can be combined to obtain the desired radiation pattern (radiation angles). This allows for reduction to the development and manufacturing costs, enabling mass production (by cheap board manufacturing process),
- designing a plastic housing with metal finished surface that thermally isolates the microwave electronics and ensure EMC through shielding from electromagnetic radiation,
- operating on frequencies in the K band (near 24 GHz) gives the higher immunity to the noise, better resolution and the spectral separation of the objects,
- reducing the power consumption by shortening the emitted pulses. This allows reduction in power consumption and improves the object separation.

1.6. The impact of the project on the industry sector

The key market opportunity is targeted to the impact of on decreasing numbers of false burglar alarms. Targeting in Europe the direct costs of false alarms: €1.8 billion p.a. police, and €1.5 billion p.a. commercial security companies. Within a 5 years post project period, medium term market penetration of the unit will result in over 45% reduction in false alarms generated by intrusion detection systems from commercial and residential customers who install this new sensor. 15% market penetration equates to the installation of 35 million new units with the new sensors (assuming an average four motion sensors per installation).

A second opportunity demonstrating widening usage is in the automatic door opener market. Annually over 280,000 door openers based on microwave sensors are sold globally. Targeting by project partners at 50% 5 year post project medium term market penetration within Europe based on the current market share held by Besam in the area of door openers built with microwave motion and direction sensors, and assuming that unit for the door opener application is more complex and more expensive, we expect to achieve the additional income.

The medium term impact of the project is to develop a non contact universal microwave Doppler detector unit that can be easily integrated as a building block for different sensors, devices and systems including applications in security, automation, road infrastructure, automotive and industrial sectors. This type of technology is hardly available at a cost allowing take up in Europe in an off-shelf configuration. As such this is extremely attractive in a growing marketplace.

The long term impact of the project is different for each SME. Specific advantages for each are as follows:

- MSL: Attain the technology for manufacturing microwave detector units for K-band. Move a product primarily aimed at the motion detection at security sector into higher value added applications.

- Cube: Gain increased skills in providing customised multilayer PCBs, which enables higher market penetration.

- Schaal: Attain knowledge on new applications for their potential products and enter these new market. They will also be able to sell individual components into expanding systems and global markets.

- RCD: Producers of radio communication antenna systems, RCD will gain new knowledge on designing and building microstrip antennas for super high frequency range. The project brings to them the opportunity for new products addressed to new market sector.

- Linwave: As a key contributor to the characterisation of antenna and microwave circuits Linwave expects that the project gives them opportunity to validate their methodology and skill in antenna and microwave circuit characterisation as well as testing and exploit their background IPR.

- S.M.A.: As a company providing alarm monitoring services, S.M.A. wish to minimise the number of false alarms caused by motion detectors. As an ultimate end user S.M.A. would like to influence the design and usability of the sensor unit to ensure that it will meet their requirements. .

Through participation in the project, each SME increased in competitiveness going beyond the opportunity to offer a specific component or service related to the markets identified, but also including the transition towards joining the new knowledge based economy with partnered exploitation of the IPR created by the project and owned by the SME proposers. Furthermore, the provision of new knowledge differentiators to the sectoral community of SMEs also provided opportunities for the Core group of SMEs to increase their perceived value to their customers as strategic supply partners with innovative product development capabilities.

1.7. A project logo.

The project logo is presented below. It will also be used to promote the products.

Figure 49: Waveshift logo.

Microwave Solutions Limited has been granted a Registered Trademark in Britain and Northern Ireland of "WAVESHIFT".

TRADE MARKS REGISTRY

REGISTRATION CERTIFICATE

Trade Marks Act 1994 of Great Britain and Northern Ireland

The *mark shown below has been registered under No.* 2411821 *as of the date* 24 January 2006.

WAVESHIFT

The mark has been registered in respect of:

Class 09:

Intrusion detection apparatus; sensors; motion sensors; intruder alarm sensors; microwave Doppler motion sensors; parts and fittings for the aforesaid goods.

In the name of Microwave Solutions Limited

Signed this day at my direction

RON MARCHANT, REGISTRAR

Microwave Solutions Ltd has also been granted a Community Trademark for "Waveshift"

Registered / Enregistré 15/01/2007

No 004869079

OHIM – OFFICE FOR HARMONIZATION IN THE INTERNAL MARKET
TRADE MARKS AND DESIGNS

CERTIFICATE OF REGISTRATION

This Certificate of Registration is hereby issued for the Community Trade Mark identified below. The corresponding entries have been recorded in the Register of Community Trade Marks.

OHMI – OFFICE DE L'HARMONISATION DANS LE MARCHÉ INTÉRIEUR
MARQUES, DESSINS ET MODÈLES

CERTIFICAT D'ENREGISTREMENT

Le présent Certificat d'Enregistrement est délivré pour la marque communautaire identifiée ci-joint. Les mentions et les renseignements qui s'y rapportent ont été inscrits au Registre des Marques Communautaires.

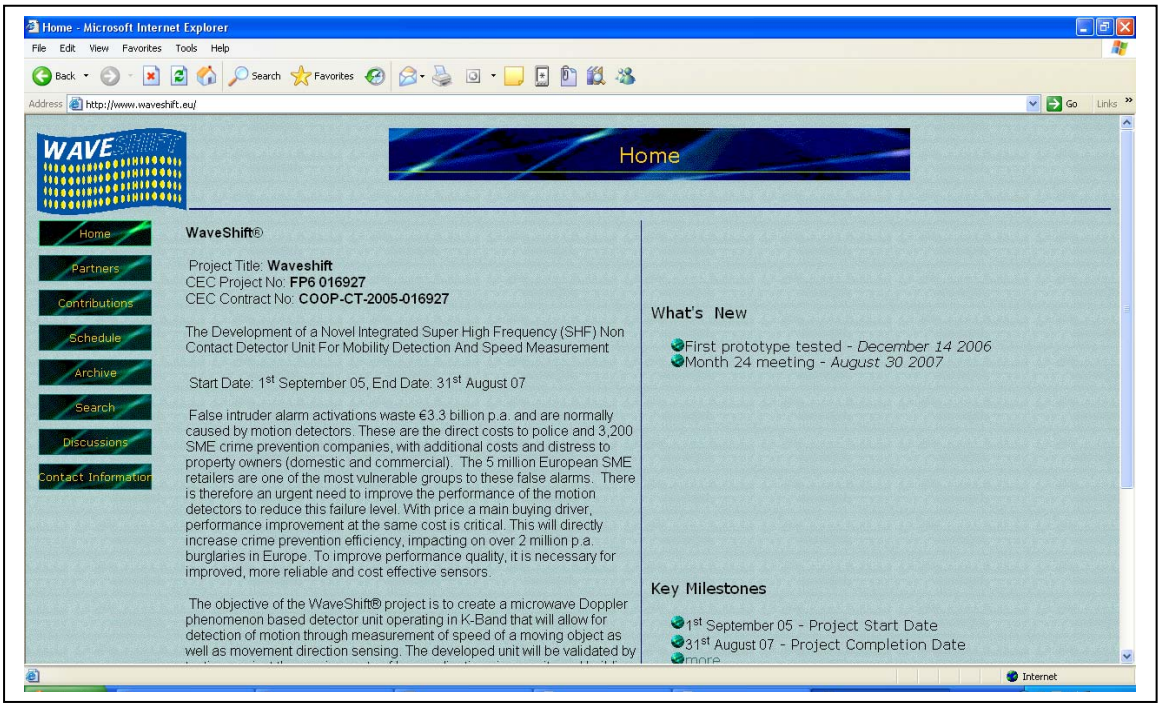
WAVESHIFT

The President / Le Président

Wubbo de Boer

1.8. A reference to the project website.

The project's website can be visited at following location: http://www.waveshift.eu.



Section 2 – Dissemination and use

This section has been prepared following the published guidelines that it should only contain results that the Consortium is ready to publish and has already obtained sufficient protection for the IPR involved.

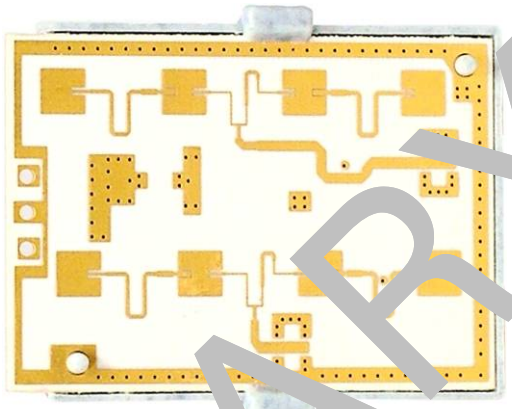
The primary thrust of the Waveshift™ project has been to develop a 24GHz motion detector module for incorporation into a wide range of consumer and professional products. Such a module has been developed and a preliminary datasheet describing the electrical, mechanical and basic performance characteristics of the module has been published by Microwave Solutions Ltd.

This datasheet is being distributed to major existing customers of MSL, who are being asked to confirm the proposed specifications match their requirements, or to identify areas where alternative performance requirements are required to meet their needs. Prototype samples of the Waveshift™ modules will be supplied to a selection of these customers in return for feedback on their experiences using the module. This feedback will be used as an input into the next phase of the development of a production version of the module.

As well as distributing this datasheet to selected customers, the successful conclusion of the Waveshift™ project has been publicised on the Microwave Solutions Ltd website at http://www.microwave-solutions.com/ in the "News Update" section. This feature allows other interested parties to request copies of the datasheet and further information about the product.

The datasheet is included below in this report.

MDU 2400
TRANSCEIVERS



Features

- Low cost
- RoHS Compliant
- Miniature Profile
- Rugged, Reliable Construction
- Reduced Power Consumption
- High Sensitivity

Description

The Microwave Solutions MDU2400 (Motion Detector Unit) is a K-Band microwave transceiver that utilises the Doppler shift phenomenon to "sense" motion. The unit, housed in a lightweight plastic housing, features a resonator stabilised oscillator, which provides stable operation over a broad temperature range in either CW or low duty cycle pulse mode and an integral receiver with a balanced mixer for enhanced sensitivity and reliability.

Applications

- Intrusion Alarms (Room, Vehicle)
- Door Openers
- Energy Management
- Home Automation
- Presence Sensing

MICROWAVE SOLUTIONS Limited

MDU2400 TRANSCEIVERS

Operation

The basic principle of operation consists of detecting the frequency shift between a transmitted and a received signal reflected back from a moving object within the field of view of the unit.
The unit produces a low level IF output signal which can be amplified and processed to provide an audible or visual alarm signal and employs low cost surface mount manufacturing techniques which are field proven as being rugged and reliable.

Electrical Characteristics

Transmitter

Frequency	:	24.2GHz nom.
Frequency Setting Accuracy	:	10MHz
Power Output (Min.)	:	2dBm EIRP
Operating Voltage	:	+5V ±0.25V
Operating Current (CW)	:	60mA max.
	:	50mA typ.
Harmonic Emissions	:	< -10dBm

Pulse Mode Operation

Average Current (5% DC)	:	3mA typ.
Pulse Width (Min.)	:	5µSec
Duty Cycle (Min.)	:	1%

Receiver (Measured in 6Hz to 200Hz bandwidth)

Sensitivity (10dB S/N ratio)	:	TBD dBm
Noise	:	TBD μV

Antenna

Gain	:	11dBi
-3dB Beamwidth		
E Plane	:	72º
H Plane	:	18º

Mechanical Characteristics

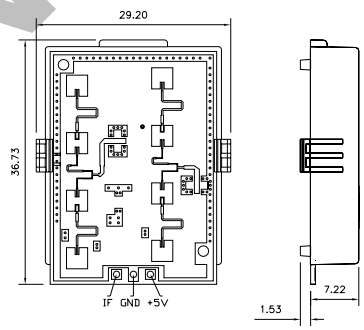
Dimensions	:	39 x 29 x 10 mm
Weight	:	10 grams
Tab Connections	:	0.1" spacing
Metallisation	:	Sn + Ni + Cu JEDEC JESD97 (e2)

Environmental Characteristics

RoHS Compliant

Power/Temp. Coefficient (over operating temp. range)	:	TBD dB
Frequency/Temp. Coefficient (over operating temp. range)	:	~25MHz
Operating Temperature	:	-10ºC to +55ºC
Storage Temperature	:	-30ºC to +70ºC

Connections



NOTES Detection range is dependent on size and reflectivity of target and S/N ratio
Doppler shift at 10.687GHz is 70Hz/m.p.h.

Model	Application	Order Code	Frequency	Comments
MDU2400	All	Cxxxaa	24.2GHz	

For further information please contact the Sales and Marketing Department at the address below.

Hamilton House, 111 Marlowes, Hemel Hempstead, Herts., HP1 1BB. ENGLAND
Telephone: +44 (0)870 122 3346
Fax: +44 (0)870 051 1413
Email: sales@microwave-solutions.com
Website: www.microwave-solutions.com

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