Three Decades of Microwave Techniques Development at the Institute of Microwave Techniques and Electronics (Institute IMTEL)

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Abstract: - **This paper describes the thirty years long development of the Institute for Microwave Techniques and Electronics. IMTEL Institute has grown autonomously, with no traditions in this field, with no specialties of its employees abroad and without any foreign license.**

IMTEL Institute has realized a great number of completely original solutions and technological methods long before they have been achieved by other similar institutions in the world. For 25 years now it represents the most advanced institution in the Southeast Europe that deals with research, development and pilot production of devices and systems in the field of microwave and millimeter wave techniques.

I. A Short History

In 1970 the Laboratory for Applied Physics was established within the Institute for Physics. It had eight full-time and three part-time associates. The scope of the Laboratory work was in the field of applied physics. The founder of the Laboratory was Mr. Dragan Kosanović, M.Sc., who later became the director of the Institute for Applied Physics.

Within the Laboratory, in 1973 the author of this text initiated the program of research and development and provided necessary conditions for development in the field of microwave techniques and electronics (including application of ultrasound).

Within a very short period of time, the Laboratory achieved noticeable results in research and development of devices and systems, which at that time were among the most modern ones in the world:

- Measurement of time with distribution systems
- Big-size digital quartz watches
- Electronics displays
- Systems for light direction of airplanes upon landing and take-off
- Ultrasound radars
- Microwave Doppler radars
- Microwave oscillators
- Antennas
- Protection systems based on IC radiation
- Geophone protection systems

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These programs represent first conceptions of the future program of the Institute for Applied Physics.

Research and development are performed autonomously, without any conveyance of experience or specializations outside the Institute.

1974–1975: first demonstrations of microwave radar and protection devices; first contracts with the Yugoslav People's Army (YPA) for outdoor and indoor protection, where the main part is microwave equipment; microwave devices and systems for protection of the islet of Vanga, one of the Brioni islets (residence of President Tito).

In 1975 the Department for Applied and Development Research was formed within the Institute for Physics. This Department developed rapidly and in 1977 became the Institute for Applied Physics.

1976-1978: Military Technical Institute (MTI) supplied us with samples and manuals of renown companies that produced microwave equipment for: NATO (France, England, USA) with a request to copy them!? Some companies of ex-Yugoslavia had already tried to do this but the copies usually had very degraded characteristics.

The Institute showed their first research results and models, with fully original solutions. In the case of miniature surveillance radar detector all microwave parts including antenna array were realized with printed technology on dielectric substrate. On the basis of this, it was possible to demonstrate that national, fully original development was possible. However, military technical experts were doubtful about feasibility of suggested solutions as they had no references (they never existed before) in the literature.

The Main Military and Technical Council, which included five high-ranking generals, , accepted the solution of Portable Radar Detector (PRD) in 8-40GHz frequency range offered by the Institute of Applied Physics, despite of disagreement with the representatives of Military Technical Institute. It was a milestone in acknowledging the Institute of Applied Physics among the most respectable research institutions by the military authorities.

1979–1991: The YPA, on the basis of demonstrated results, entrusted the Institute for Applied Physics with some 15 research and development projects in the field of microwave techniques and digital signal processing, including realization of test samples for already developed devices such are:

- Miniature portable radar detectors
- Infantry radars of small power
- Infantry radars of higher grade with pulse compression
- Systems for surveillance of radar signals
- Radar jammers
- Microwave systems for systems for unmanned aerial vehicle of high performances
- Radio systems for communication in spread spectrum with high protection level
- Systems for surveillance and jamming of communications in spread spectrum

Until that time, miniature portable radar detectors for ranges up to 40GHz were realized in waveguide techniques. This was the first radar detector up to 40GHz realized in planar – printed technique integrated with printed antenna.

As a result of a big research and development demand of the Yugoslav People's Army of that time, in the 80's, the Institute paid scholarships to some 15 students of microwave technique at the Faculty of Electrical Engineering in Belgrade. This was also the beginning of co-operation with the Faculty of Electronic Engineering in Niš.

All mentioned projects used only research and technological solutions realized at the Institute, without any foreign license.

Realizations of models of microwave circuits, devices and systems, of course, largely depended on technological possibilities. In the course of the 70's there was neither tradition nor experience nor equipment for realization of microwave circuits. Practically, we started from point zero.

Although without any experience, we started with original solutions that were not used at that time: (1) up to that time for circuits at higher microwave frequencies, so-called "hard" dielectric substrates were used, such is alumina (Al2O3) or fused silica.

- We were the first to start application of so-called "soft" dielectric substrates based on Teflon for frequencies up to 40GHz (the colleagues that were on specialization in England at that time gave remarks that these frequencies "do not operate on such substrates").

- Two years after, a paper was published in the Microwave Journal demonstrating that soft substrates can be used for millimeter frequencies, which is much cheaper.

(2) In the 70's linking of subminiature microwave components was performed only by conventional bonding.

- Due to the lack of appropriate bonders, we began to connect the subminiature microwave components by epoxy bonding (glue based on gold), which turned out to be very successful as microwave circuits realized in this way passed very strict military climatic and mechanical tests.

- After a few years it was published in the literature that epoxy bonded microwave circuits can fulfill military standards.

This case also showed that our technological solutions were avant-garde.

All technological operations on microwave circuits were performed by very simple means, without even one specialization or study stay abroad. I would like to point out that the only experience and help in technological operations was obtained from the semiconductor factory within the Electronics Industry in Niš.

The Institute was the only institution in Southeast Europe that dealt with research and development of microwave devices at millimeter wave range.

It should also be pointed out that in the 60's a group of researchers lead by Prof. Marinčić was engaged in development of a small capacity radio relay link at 8GHz at the Institute ″Mihajlo Pupin″.

In 1990 the Institute for Applied Physics changed its name into the Institute of Microwave Techniques and Electronics (IMTEL). At the beginning of disintegration of SFRY, in 1991, the Army stopped financing the military projects and the Institute began to turn to civil projects, i.e. to research and development of microwave telecommunications devices and systems.

In 1993 IMTEL divided into two separate companies: IMTEL-Computers and IMTEL-Microwaves. Within the company of IMTEL-Microwaves there was formed a scientific and research institute that was registered with the Serbian Ministry of Science and Technology.

II. Cooperation with Foreign Institutions

By the end of the 90's and at the beginning of 2000's associates of the Institute IMTEL had scientific co-operation with the University of Dresden in research of microwave systems with integrated smart antennas. The Institute also co-operated with R&D Center of Sony for Europe, especially in research of various types of printed antenna structures at frequency ranges between 2GHz and 75GHz:

- Printed antenna with circular polarization and conical radiation pattern for frequency range of 5GHz
- Sector printed antennas with radiation power widths from 60°, 90° and 180° in frequency range of 2.2GHz
- Wideband antenna arrays with linear polarization in frequency ranges of 2GHz to 4GHz, 4HGz to 8GHz, 35GHz to 50GHz, 50GHz to 75GHz
- Printed antenna array with circular polarization in frequency range of 60GHz
- Printed antenna with omni-directional radiation characteristic for frequency range of 5.2GHz.

III. CURRENT PROGRAM OF THE INSTITUTE

Current program of the Institute includes the following:

- Digital radio relay devices of 2 Mb/s, 8 Mb/s, 34 Mb/s and 155Mb/s capacities in frequency ranges of 13 GHz and 23GHz
- Microwave components in frequency band up to 40GHz
- Antennas and antenna systems in frequency bands up to 40GHz
- Various types of digital multiplexers
- Analyzer of digital transmission quality for 2 Mb/s, 8Mb/s and 34 Mb/s rates.
- Basis band units for 2 Mb/s, 8Mb/s, 34 Mb/s and 155Mb/s rates.
- Active repeat stations with solar power supply.
- Long distance radio relay systems at 2.5 GHz
- Semiconductor microwave amplifiers of 10W to 20W in frequency bands between 4 GHz and 8 GHz
- Systems for surveillance, measurement and control of telecommunications networks
- Power supply units
- CARRD.NET program package for radio relay lines design.

So far the production department of the Institute has delivered over 450 radio relay terminals (IDU + ODU units). Also, the upgrade of Ericsson ML13 was performed. We have also reconstructed over 270 microwave transmitters and terminal units of foreign produce (Telettra, Siemens, Ericsson, GTI, Marconi, etc.).

The production department of the Institute has produced a large number of hand-set analyzers of digital transmission quality (BER-meters), with which we have furnished all support centers of TELEKOM SRBIJA, EI Konsing, etc.

All above mentioned devices meet contemporary international recommendations and standards (ETSI and ITU-).

Institute IMTEL can offer its services in the following fields:

- development and production of electrically and mechanically compatible microwave and digital components for upgrade of radio relay devices of other producers,
- radio relay network design,
- technical consulting in the field of new microwave technologies and applications in the field of novel microwave technologies and applications,
- feasibility studies in the field of microwave communications systems and special purpose systems.

IV. RESEARCH AND DEVELOPMENT PROGRAM OF THE INSTITUTE IMTEL

Basic research and development activities of the Institute will be focused on:

- research of printed filter structures suitable for integration with other microwave active and passive circuits,
- research of active antenna structures in microwave and millimeter wave ranges which are used in telecommunications and radar systems,
- new generation of radio relay links.

As per technical and technological solutions, whose research is in progress, the new generation will bring an enormous advance compared to the solutions of renowned producers of radio links, especially in the following:

- high level of integration,
- miniature dimensions and compactness,
- high level of compactness,
- high reliability,
- low price.

The new generation of digital radio links will be produced in all actual frequency ranges, including 26GHz and 38GHz, in all rates to 155 Mbit/s.

Beside the above stated, the research and development will include the following:

- further development of surveillance systems, measurement and control of communication systems,
- active antenna systems at frequency bands up to 75GHz,
- program packages for radio relay lines design,
- radar systems,
- lightweight unmanned aerial vehicle for terrain surveillance, as well as for other purposes.

V. SCIENTIFIC ACHIEVEMENTS OF THE INSTITUTE

In the 90's the Institute IMTEL was an important participant in the following scientific projects: "Electromagnetics, microwave techniques and optical communications" as well as "Telecommunications", financed by the Serbian Ministry of Science and Technology. The Institute was also the realizer of two strategic projects in the field of technological development: "Microwave Systems for Transmission of Digital Signals" as well as four innovative projects, also financed by the Ministry.

Today the Serbian Ministry of Science and Environmental Protection co-finances the following projects realized by the Institute:

1. "Digital radio relay links of high capacity (51.8 Mbit/s and 155 Mbit/s)"
2. "Fixed wireless Internet network"

3. "New generation of millimeter links based on composite nanostructured materials".

In the 80's, the Institute's associates published papers that included only about 15% to 20% of original and actual solutions realized at the Institute, as it was prohibited to publish papers that had anything to do with the military projects. Some of these solutions were published in the mid 90's, since they were still inventive ten to fifteen years later!

Another reason for a comparatively small number of published papers in comparison to results is ceaseless pressure to gain applicable results as soon as possible with a new task awaiting.

Also, many important results have been published only at conferences (due to lack of time needed for a more detailed preparation of the paper).

Crucial criterion to estimate scientific level of papers presented at conferences is their citation index in journals with a high IMPACT factor, as well as citation index in important international monographs.

The majority of papers written by associates of the IMTEL Institute presented at international conferences have been cited in journals with high IMPACT factor: IEEE Transaction on Microwave Theory and Techniques, IEEE Transaction on Antenna and Propagation, Microwave and Wireless Components Letters, Electronic Letters; as well as in monographs published by renowned publishers: Artech House, John Wiley & Sons, etc.

Despite limited publishing possibilities, our work has become very noticeable in the world in the field of microwave techniques, especially in the filed of planar antennas.

Associates of Institute IMTEL have been authors or co-authors in six international monographs, published over 350 papers in renowned world journals and at important international conferences, as well as over 400 papers in national journals and at national conferences.

Besides national awards, Institute's associates have also received the following international awards:

- Maxwell's Award
- The IEEE Third Millennium Medal 2000
- Tesla's Award for superb technical solution

as well as over 20 prizes and medals of domestic institutions.

VI. Human Resources and Technical Equipment of the Institute

Despite brain drain of researchers and experts over the past two decades, due to sanctions and aggression against our country, which was typical for all institutes in Serbia and Montenegro, Institute IMTEL has retained its researching and scientific potential, i.e. the majority of its associates.

As per scientific results as well as according to realizations in the field of microwave techniques, the Institute represents the most successful institution of its kind in Southeast Europe.

At present, the Institute employs over 40 experienced researchers and highly specialized experts in the field, among whom 12 M.Sc.'s and Ph.D.'s. Other associates also possess precious experience and noticeable results in national and international terms.

The Institute has high grade measurement equipment for bands up to 50GHz, as well as middle grade equipment for frequencies to 110GHz. We also have technological equipment for production of microwave circuits in various techniques.

All solutions and realizations applied to devices and systems realized at the Institute have been carried out without any license.

The majority of applied solutions are fully original and adjusted to technological possibilities of the Institute.

VII. Conclusion

Institute for Microwave Techniques and Electronics (former Institute for Applied Physics) originated form the Department for Applied Physics within the Serbian Institute for Physics, which started its activities with 8 associates.

In the course of the 70's the Institute went through great expansion and became the only institution in Southeast Europe that is successfully dealing with research and development of microwave devices and systems at higher microwave and millimeter bands.

In the 80's the Institute achieved results of the highest level in the field of microwave and millimeter wave techniques as well as in the filed of digital signal processing in military domain. At that period, a relatively high number of associates obtained high academic titles in these fields.

It was our disadvantage that we had to respect prohibition of paper publishing as 90% of activities referred to military projects. This was why official scientific results were far below the real state of affairs.

In the 90's the Institute turned towards civil projects and in a very short time reached competitiveness on the market, even in competition with renowned multinational companies.

Apart from unfavorable circumstances, as far as scientific affirmation is concerned, Institute's associates are authors or co-authors of a number of monographs published by renowned international publishers, of some 750 scientific papers, half of them published abroad, and received three international and some 20 national awards.