Opening speech, 15 August 2016, EMTS2016, Ari Sihvola

Dear friends of radio science, ladies and gentlemen!

We are here – in this beautiful building designed by Alvar Aalto – we are here to share our most recent research results on radio science, electromagnetics, and their applications. This field is multidisciplinary by its nature. There are many entrance avenues into it. As we may come from different backgrounds, it is probable that not all of us hold the same perspective into the field of radio science. And that is perfectly fine. In the following, I shall try to explain how I see the substance and extent of radio science. I add that my understanding of the term “radio science” is rather inclusive.

Radio broadcasting, radio waves, radio receivers – these are terms that we hear in everyday talk. But how did the term, radio, enter language? — To understand the present, we need to start from yesterday.

Even if radio waves, electromagnetic radiation, from natural sources, has filled our environment from the beginning of times, there has not been a name for it. Ancient cultures did not talk about radio, nor did anyone in the Middle Ages. Isaac Newton does not mention it, nor Michael Faraday. It was only after the experimental confirmation of the existence of electromagnetic waves, by Heinrich Hertz in 1880’s that the term “radio” started to appear in scientific and popular literature.

The first traces of the use of this term can be found in written documents in the end of the 19th century. “Radio” appeared as a prefix in terms like radio-phone, radio-meter, or radio-conductor. The meaning, however, of these words has changed in the course of time. And also: the use of these terms in the time before wireless communications did not refer to radio waves. It also took a long time of unstabilized terminology before “radio” conquered over “wireless telegraphy” as a label for transmission of information through air.

The founding pioneer of the use of radio waves in telegraphic communications was of course Guglielmo Marconi. With clever use of spark transmitters, wire antennas, and coherers, he managed to transmit signals over a distance, behind hills, later over the Bristol Channel in England, and finally crossing the Atlantic. Less known are the parallel experiments of Alexánder Popóv, who, simultaneously with Marconi, demonstrated wireless transmission using radio waves. Even if he was interested in using his device for detection of thunderstorms, he also used radio communications in a marine rescue operation. This happened in 1900 between the city of Kotka and the Gogland island. The city of Kotka is, by the way, present-day Finnish territory. Hence Finland, this small country, can claim part of the glory of the invention of radio.

The origins of the term “radio” lie in radiation: “radius” from Latin means a beam of light, a ray. The same root gives growth to another concept: radioactivity. As it happens, exactly at the time of the discoveries of Marconi and Popov, in 1896 Henri Becquerel experimented with phosphorescent materials and found the penetrating power of invisible radiation from uranium salts, later coined “radioactivity” by M. et Mme Curie. Note, however, the difference: Even if we — radioscientists — even if we are radioscientifically active, we are not radioactive.

In early radio communications, the transmission signals were generated by spark gaps. This resulted in oscillations fast enough to create propagating electromagnetic waves, but the unfiltered sharpness of the sparks produced broad-band emissions. Therefore simultaneous transmissions interfered with each other, making it in the worst case impossible to maintain several communication links at the same time. Clearly, coordination between operators and countries was needed. The first international conference with focus on radio took place in 1913 in the Royal Palace of Laken, Belgium. Another one was held in 1914. [kuva] The First World War interrupted co-operation for five years. But finally, in 1919, URSI was born. [kuva]

URSI stands for Union Radio-Scientifique Internationale, the international union of radio science. Operating within the umbrella of ICSU, International Council of Science, its mission was and still is to stimulate and co-ordinate research, applications, and scientific exchange in the fields of radio science.

The motivations to establish, a century ago, this radioscientific organization were quite practical, like solving path-loss and interference problems. But the mission of URSI started soon to reach higher scientific ambition levels. One of the intriguing and challenging problems was caused by ionosphere: how does ionized plasma, biased by the Earth's magnetic field, affect the propagation of radio waves? The mystery of a reflecting layer in empty-looking sky had puzzled physicists from the time of Marconi's trans-Atlantic link. With radio soundings, progress was made in 1920's to map the layered structure of ionosphere. Later, the close relationship between ionospheric radio propagation, geomagnetism, and solar activity was established.

Furthermore, radio waves reach beyond our planet's atmosphere and magnetosphere. Indeed, radioastronomical observations have disclosed such a variety of unanticipated new phenomena that we have experienced a revolution in our understanding of the universe and cosmology, thanks to radio science. As examples, I only mention the discoveries of quasars (highly red-shifted objects in the deep, deep sky), pulsars (cosmic lighthouses with ticking pulse emissions from strange rotating neutron stars), and the microwave background radiation (the three-kelvin noise into our radio ears, arriving isotropically from everywhere).

Along with these developments progressed the conquest of space. Space age began with the launching of the Sputnik satellite. (As a footnote, this happened exactly when I was born, beginning of October 1957.) Space technology is intimately connected to radio engineering and science. Man-made satellites made it possible not only to study the universe without atmospheric aberrations that plague earthbound receiving systems, but also to turn the antennas down, to look into this pale blue dot — to paraphrase astronomer Carl Sagan. Unprecedented knowledge of dynamic processes of the geosphere and biosphere is hidden in radio spectrum emissions of our earth.

And I could go on and on with these examples.

In fact, I will.

Coherers, vacuum tubes, or even spark gaps were used to detect the radio signals in the early days of wireless. However, a fundamentally different development took place with solid-state electronics. Non-linearities in junctions involving semiconducting and other materials produced a natural rectifying effect for alternating currents. The stability, compactness, and finally, integrability of such devices pushed for a truly disruptive technological revolution.

In fact, not all scholars were prepared to appreciate these developments. I found, from obscure archives, the following quote by Jonathan Zenneck [kuva] (the Zenneck wave is fundamental concept in radio propagation, and also, Zenneck served as Vice President of URSI in mid-20th century). Reflecting on piezoelectric crystals, he said: [lisäkuva]

"If a gentleman had […] told me that he made an invention by means of which it was possible to excite elastic vibrations in quartz crystal up to a frequency of some millions per second, I would have treated him very politely but would have recommended that he see a doctor."

We can certainly sympathize with Professor Zenneck's concern for the mental health of a colleague. However, the illness of this imaginary gentleman was not to be cured. The drastic evolution of solid-state electronics was irresistible. It progressed in quasi-deterministic manner, pushed by human ingenuity and advances of materials science. The transistor of late 1940's seemed a miracle. The advent of laser and quantum electronics in 1960's extended the spectrum of coherent radiation into optics. And as I see it, the same winds are blowing in today's radioscience: think only of the recent developments in plasmonics and metamaterials.

Unraveling Nature's secrets forms part of the core mission of URSI. Apart from the scientific responsibilities, there exists also a second imperative.

Science has the obligation to serve society and mankind. It seems that demands in this direction have become more and more pronounced in recent times. External policy makers are looking for cost-effectiveness in public spending, at least in times of financial austerity. Research needs to have societal impact.

A connected tendency is that the problems that scientific research is expected to approach are global, obscure, and vaguely defined. The political and scientific communities speak about *wicked problems.* Wicked problems are by nature transdisciplinary, they touch several fields with complex interdependencies. The requirements and boundary conditions are hard to recognize. The solutions to the problems are not right or wrong. In the worst case they are impossible to solve. As examples of wicked problems one may mention pandémia, shortage of natural resources, and global environmental change.

How can radio science help in this scenario? It would be megalomanic to consider radio science as universal remedy to such problems. But I would still claim that radio science is a very powerful weapon in the fight against certain wicked problems. As I have pointed out in my previous examples, radio science is truly multidisciplinary. It spills over to several neighboring fields of science and technology. Many radio scientists in their everyday work have to interact with professionals from different backgrounds, expertise, and traditions. Remote sensing of the environment, which is one of the core fields within URSI, is one of the examples of such solution-driven impactful endéavors.

I started the historical journey in this talk from first radio transmission experiments. Those exhibited a revolutionary advance in science and engineering. But unlike many other scientific breakthroughs, radio was not discovered by accident. What made radio possible was the understanding of the fundamental laws governing the interaction between electric and magnetic fields. These were formulated by James Clerk Maxwell in the 1860's.

Maxwell's unification of electric and magnetic field theories was a mind-boggling achievement. And even that is an understatement. Dear colleagues, please remember: Radio science rests at a foundation - as solid as can be found - in the whole domain of science: electromagnetics.

We'll learn much about Maxwell's electromagnetism in this symposium. Here, instead of citing any of his scientific works, I will refer to *Recollections of a Dreamland,* which is a poem, my favorite among the poems written by Maxwell. In the closing lines of this poem, Maxwell describes the duties of the day that await him. I think that he sends a message to all radioscientists by the following words:

Let me wake, and see my duty / lie before me straight and plain.
Let me rise refreshed and ready / to begin my work again.

Quite a responsibility.

Ladies and gentlemen:

With this brief review I wanted to underline the impact and importance of radio science and electromagnetics in modern culture.

Let it motivate all of us during the next four days to contribute to the success of the EMTS conference by our discussions, interactions, presentations, and togetherness.

Welcome to the URSI Electromagnetic Theory Symposium!