# Antenna and Propagation Effects on HF Ionospheric Studies and Applications

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After a short overview on the activities of the institute (IETR) and those of the communication and propagation group of this institute, a general subject is presented: how antennas and propagation can act on studies and be applied to the definition of new systems in the HF band. The subject is limited to ground to ground links using heterogeneous antenna arrays set up with active antennas. Applications to communications and to direction finding illustrate the presentation.

HF (3 - 30 MHz) ground-to-ground radio links over large distances (from 100 km to several thousand of kilometres) use the ionosphere as propagation medium. This medium has been studied since the beginning of the last century and a great number of books or articles were published on this domain. This doesn't mean that everything is known.

The definition of new systems adapted to transmissions requires the modelling of the propagation of electromagnetic waves in a more realistically way as possible. From this objective, it appears that several aspects must be taken into account to understand and solve the whole problem:

- A good description of the ionosphere is necessary,
- The propagation aspects in such environment have to be introduced: the medium is inhomogeneous, varying in time and anisotropic as a result of the influence of the terrestrial magnetic field. Theories of electromagnetic waves propagating in an ionised medium are well known, particularly the magneto ionic theory applied to the ionosphere by Appleton and developed by many others. The results of these theories show that two different waves (O and X) can propagate independently in the ionosphere with complementary polarisations,
- A global description of the ionosphere behaviour through the electron density profiles is also important,
- Forecast for a given radio link can bring essential elements.

However, when propagation conditions between two points are known, it does not mean that the mathematical expression of received signal can be written easily: previous knowledge of the medium and the scalar channel model are insufficient and a better specification of the transmission is necessary. It is necessary to propose a model of signal allowing tests of systems, including both ionospheric channel and antenna effects. The development of new systems in simulation and in communications, or direction finding, has to lean on the most complete possible models.

In the presentation, most aspects of the subject are described, and references to other complementary published works are also given.

The conference contains the following steps:

In a first part some physical or mathematical aspects of the problem are developed as:

- The limitations of the subject (ground to ground links, no meteoric trails, no scintillation, no noise modelling, and no analysis of trans-ionospheric propagation….)
- The previous hypothesis (dispersion bandwidth limited, SISO links…) inducing transmission systems with limited bit rates and direction finding systems with poor performances. The introduction in the applications of SIMO and MIMO techniques leads to study the problem under different topics:
  - A propagation and forecast model, developed in the laboratory and sufficiently accurate (in distance for example) to determine dispersion bandwidths relative to each mode or path is described,
  - A received signal model (using a vectorial form), for ground to ground links, taking into account simultaneously propagation and antenna effects, is presented under various form and, with the help of experimental data, compared with those already published. The consequences for HF systems are shown inducing the definition of new architectures in:

- Transmission (particularly for SIMO and MIMO systems),
- Direction finding and SSL applications.

The development of digital techniques infers of numerous changes but also open the way to new possibilities. For example, digital communications tend to replace analogue communications, allowing a better quality in the understanding of the message and, in sometimes permitting image transmission.
So in a second part and to illustrate the previous developments, new transmission systems using digital modulations and direction finding apparatus are described. Numerous experimental results obtained with several antenna arrays, some of them using collocated antenna, are given. The performances of these systems are compared with recent results published.

Finally our last experimental set of data about HF antenna arrays calibration shows the validity of all these studies but also that some work has to be done yet.

In the presentation numerous paper references are given.

## Biography

Louis BERTEL is born in 1942 in France. After studies at the University of Rennes, he became "assistant professor" and then "maitre assistant professor" in the same University. Then he was appointed to a post of professor (1980) at the IUT (Institut Universitaire de Technologie) of Lannion (in Brittany) where he became the director of the department of "Physical Measurements".

After 3 years in this post, he joined the research laboratories of France Telecom (CNET) where he stayed 5 years; during that time he was in charge of the conception and then the construction of an HF Radar (the Losquet Radar). He came back to the University of Rennes 1 in 1988 as director of a small laboratory (radio communications). In 1992 this laboratory was included in the "structures rayonnantes" Unity (associated with the Centre National of Scientific Research). He became the director of this unity from 1995 to 2000.

In 2000 he was appointed by the minister of research to be his representative in Brittany where he stayed during 5 years with the charge of all the research activities of the west part of France. He is now returned as professor in his laboratory, became IETR (institut d'électronique et de télécommunications de Rennes), where more than 250 people are working.

During all this 44 years he was in charge of various studies, in physic, electronic, electromagnetism, earth sciences, telecommunications:

- first in transionospheric propagation using the first low orbiting satellites (from the US and then from France) where he was involved in the modelling of the differential Doppler shift and the Faraday effects,
- then in the effects of atmospheric gravity waves on the behaviour of the electron density profile, these waves were observed from Differential Doppler shift measurements (using the TRANSIT system),
- during his stay in Lannion he was in charge of the conception and the construction of an HF Radar, set up on the island of Losquet in Brittany. Several applications where defined (direction finding, characterisation of the electronic profile, studies of the sea state…),
- coming back to the University of Rennes 1, he developed, in relation with several industries and with the department of defence, different works in relation with propagation (in all the bands) and systems.

It is important to mention that Professor Louis BERTEL has a great experience of the systems (he built himself several of them) and in the behaviour of such systems in various conditions of propagation.

The last years he was involved in the definition of new systems (for HF transmission or direction finding applications or in VHF-UHF for television links with mobiles) using a particular approach including simultaneously, in the definition of the architecture of these systems, propagation and antenna effects.

He published a great number of papers, reports and communications.