PhD thesis proposal in the context of a CIFRE
(Industrial Conventions Research Training)
As soon as possible depending on the recruitment

Calibration of active antennas for radar application

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Scientific background:

Radars using electronic beamforming are composed of multiple (> 1000) radiating elements connected to the active components of the transmitter and receiver. The performance of these may drift over time and therefore monitoring of the antenna radiation is no longer controlled. It is therefore necessary to regularly calibrate transmission and reception channels to compensate for the drift.

Currently this calibration is performed by transmitting known signals in each channel by specific circuits (switches, couplers ...). The objective of this thesis is to search alternatives knowing that the number of radiating elements increase but also the power of embedded digital processors.

One idea is to use the natural coupling between the elements of the network to replace the couplers. But this idea faces the problem of dynamic signals on transmission and reception channels. In general, for a radar operating mode (target far away from the radar), the transmission and reception channels of the radar does not operate at the same time. On the other side, it will not be the case during the calibration procedure : transmission and reception will operate at the same time. The consequence is that the power output can saturate strongly or destroy the reception channels.

A first research will be to calculate by an electromagnetic study the distance between the transmitter and the receiver in such a way to not estroy the receiver. But in that case the receiver will operate in saturation mode. It will then be possible to determine the non-linear transfer function between the transmission and reception channels. A second research is to estimate the linear function from the nonlinear function. This approach is completely new because usually reverse operation is performed, the nonlinear behavior of RF components is characterized cad (power amplifiers, mixers ...) by linear functions (Volterra series ....). It will require excellent background in mathematics and physics for this part to establish models and validate them by measurement.

Work plan of the PhD project

1st Year:

The first year will begin with the study of radar using electronic beamforming to:

- Understand the functions of radar and its environment

- Know the characteristics of transmitters and receivers components (frequency bands, signal dynamics, noise ..)
- Calculating the relationship between the uncertainty of the beam steering and the amplitudes and phase of the signals radiated by each of the radiating elements, taking into account the couplings.
In a second step, the coupling between the elements will be evaluated by an electromagnetic simulator and validated by measurements.

2nd Year
Research will focus on the evaluation of the amplitudes and phases of the signals on the transmission and reception channels. It will be based on a priori characterization methods and nonlinear modeling of active components. The objective is to predict the value of the linear transfer function between the transmission and reception channels of the radar (operational mode of the radar when the target is far away) from the knowledge of the non-linear transfer function (calibration mode of the radar).

We begin a priori by the study of a power amplifier in linear and saturated mode to establish the mathematical relationship (see for example the Volterra series ..) between linear and nonlinear functions. The proposed solutions will be validated by electrical simulation and measurement.
This method is then applied to the case of the radar. The complexity is the number of transmit and receive paths to be treated and the coupling problems.

3rd Year
The values of amplitudes and phases of the signals were determined at the end of the second year, it will establish the calibration procedure to provide the correction complex factor on each of the radiating elements and validate the proposed measurement technique.
This past year will end by writing thesis.

Industrial context
Industrial supporting this thesis is one branch of Thales called Surface radar. It aims to develop and produce surveillance radars of different ranges, responding to various operational needs.
The product range of surface radar from Thales is the most comprete on the market. It meets the needs of the sky and sensitive areas surveillance in both civilian areas (civil radars) and military (coastal surveillance, battlefield and counter-battery ...). The design and manufacture of these radas are made in three centers: two in France for the land and civil applications, one in Holland for naval activities. This thesis will take place in conjunction with the research center located in LIMOURS (Paris region).

Knowledge:
RF, antennas, linear and nonlinear modeling, signal processing, Radar
Software ADS, CST, matlab

Send resume, cover letter and letters of recommendation to Xavier Begaud-Telecom ParisTech (address above).