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Very high frequency design and modeling for radar interface: A Review

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Abstract: *Design modeling of vey high frequency interface in radar application has been an area of interest in recent past. Developments toward improving the performance of high frequency interface in radar design is been focused. Various works in this approaches were developed where focus were made on developing coding precision and performance improvement in terms of computing overhead and resource utilization. This paper present the past development in this area towards radar designing and interfacing in high frequency applications used for target monitoring. The developed approaches of radar interfacing using various approaches of signal processing and tuning operation is outlined. The past developments, and their possible enhancements were outlined.*

Keywords**:** *very high frequency, radar interfacing, target modeling.*

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I. Introduction

Very high frequency (VHF) communication has gained a rapid utilization in various domains of wireless communication. Such communication are affected by the propagation and components utilized. In interfacing, wireless radars are used for signal exchange and tracking operation. Radars are used for navigation or satellite remote sensing that work with a microwave band range, while high-frequency radars placed on land-distribution broadcasts are used to monitor various target movements. Many approaches have been built over the past years using modern electronics and computer systems to improve the interface efficiency. However, the effectiveness of these approaches are limited by the propagation medium which causes scattering of the frequency component, and the design of the measuring system. High Frequency system concentrates on emerging new technology in signal processing and conditioning to improve the performances. Various past observations ensured that with the distribution of the range is reduced with minimization of conductivity. HF radar uses different ways of solving the range and azimuth using different spatial resolution methods. For solving the range issue with short pulses and frequency controlled chirp sequence for azimuthal decision with beam composition for finding direction. The capabilities of HF communication were much evolved in world war-II where various approaches of signal scattering over different atmospheric layers were developed. Today, various approaches of communication, used for data exchange, tracking, navigation etc., are used under HF/VHF/UHF range. The evolution of HF communication has outcome with various advancement in communication, however the processing overhead, estimation accuracy and design constraints yet need an improvement for providing better service quality for existing and new applications.

II. VHF Communication

VHF communication provides a long-distance communication over ionosphere. The communication system needs interfacing transmitter and antennas, and there is no external infrastructure needed in communication. Hence these systems can be easily established in remote areas or when a natural disaster occurs. These systems use a local PSTN to interconnect terminals for remote accessing of data over wireless network for various remote monitoring and navigation applications. In communication process the system has a transmitter, placed over a synchronous network, and antenna. The receiving system includes an antenna, a linked network, and a pre amplifier unit at the receiver. Many of the VHF devices work at 30-300MHz spectrum where each terminal is allotted with frequencies of different range to frequency bands for communication. A representation of the frequency band resolution is presented in figure 1.

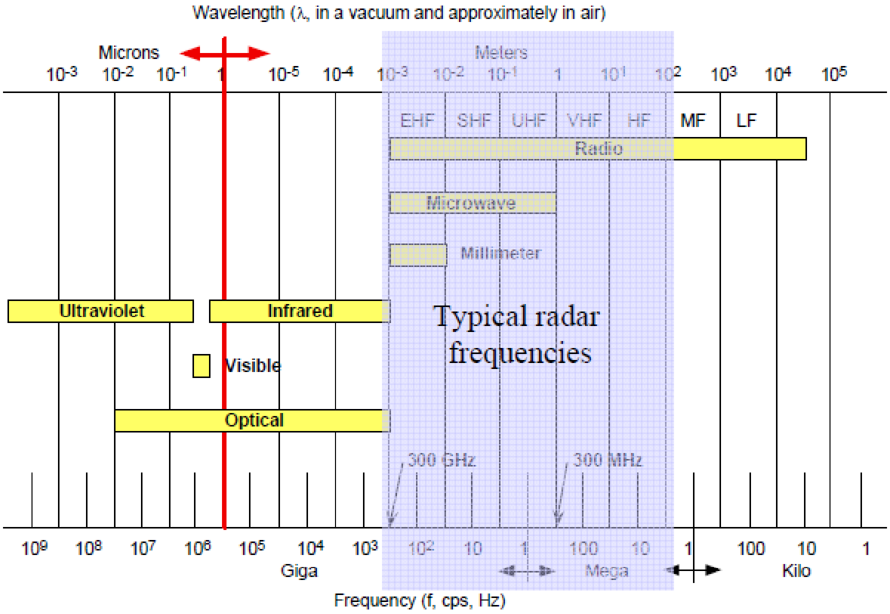


Figure 1. Frequency radar band representation in frequency spectrum [51]

The communicating system are interfaced with broadcast antennas to exchange data [1]. In the VHF communication for long range transmission, a low angle radiation is needed. As the ionosphere develops an elliptical polarization, the movements of the antennas are not compatible. In the exchange, logic cone differential transmission is carried out by a detectable beam signal using system such as yaw (using specified frequency) or using a log-periodic dipole array [2] where the bands are repeated. The gain observed ranges in 3-10dB and the low angle antennas are basically defined as monopoles. Other systems [3] use dipoles or loops to have better performance in high angles. Whips (2-5 m in length) are used for mobile applications, where loading is usually used to minimize the ground loss. Random cables are commonly used to improve the feasibility of installation. The antenna is interface to connect the uplink only to a limited number of frequencies or a limited range. An antenna tuner provides the same impedance that allows it to operate in a synchronous manner. In modeling of a transmitter unit, the basic constituting elements are a frequency synthesizer, frequency converter, modulator, and a RF-power supply. Here the peak power is set to a value of 10W-1KW [4].

Advanced interface systems are designed with a digital signal processing (DSP) and controlled by microprocessor units to offer higher performance in transmission and decision approach. In many applications of very high frequency transmitter class-B type [5] amplifiers are used. The received signals are interfered with atmospheric interferences and the receiver operates as a tuned active antenna unit with a short whip of 0.5m connected to preamplifier having a common impedance value. However such antennas are effected with inter modulation and sensitivity minimization by overloading and high magnitude signal transmission. The propagation of the signals is made at ionosphere layer which are ionized by the ultraviolet and X-rays at upper atmospheric layers [6, 7]. The reflected signal travels via different path having varying frequencies and varying distances. Based on the conditions, time of transmission, latitude, period, environment and sun conditions the effect varies. To develop signal prediction, various estimation approaches were developed through estimation algorithms such as IONCAP, PROPMAN and MINIMUF [9]. In different VHF communication, the propagation is based on the sky wave or terrestrial propagation, where the signal reflection and refractions offers a large diversity in signaling strength and estimation accuracy [10]. Here, the radar functionality depends on the transmitter block, electromagnetic radio wave for target, diverted power, and noise energy [11]. The application radar interface is as outlined in figure 2.

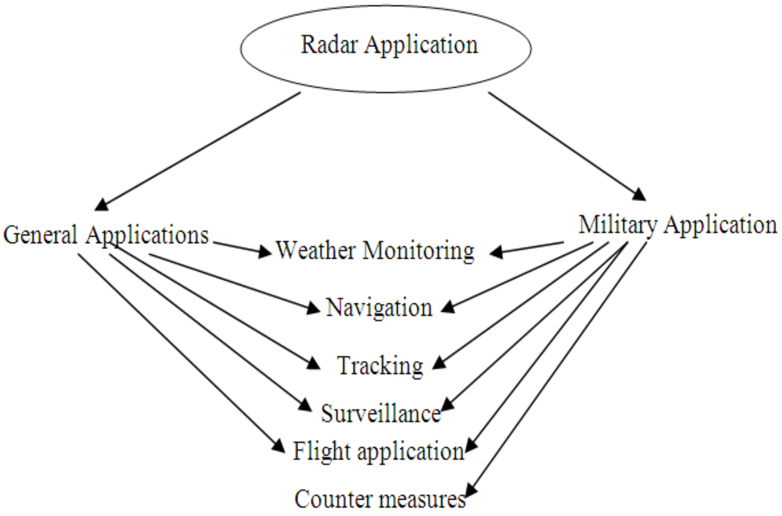


Figure 2. Applications of radar interface

The reliability of the transmission is also seen in comparison with estimates from different conducting fields of propagation. A mono static approach [12] was defined for the data exchange, where the transmitter and the receiver are placed at a fixed locked position and signals are processed for estimation. Hence, there is multiple Doppler spectrums observed whose frequency are derived by the phase velocity of scattered signals. The estimation of the Doppler determines the scattering of the Doppler spectrum [13]. In the VHF communication, pulses of signals are used for target detection [14], where the reflected signals are detected as echoes to obtain the range value. The estimation process for the detection of this reflected signal eliminating the noise level depends on the surface of target and the medium it follows. An illustration of the basic target detection model is illustrated in figure 3.

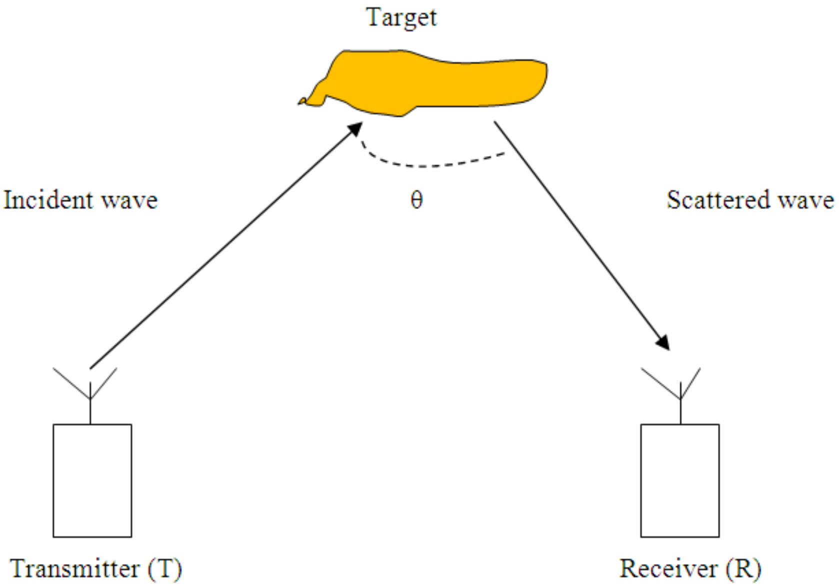


Figure 3. Target detection approach in radar interface

The estimation approach defines the selection process observing the echo of selected signal and measuring the estimates for minimizing the false alarm rate (FAR) by correlating the echo signal level with a predefined threshold value [15]. The estimate of minimum tracking error is taken as decision. To improve the decision capability, in [16] a close proximity, where the transmitter and receiver unit shares a common region is presented. In the development of communication for various tracking system, different countries have developed radar systems. A costal ocean dynamic radar (CODAR) was developed by NAAA [18].

A Marconi ocean surface current radar (OSCR) system [19] was developed in UK. Barrick Seismond [20,12] was developed by United state and Germany, which was tested over different target detections [22,23]. Similar development of radar system were observed in countries like, Canada, [24], UK, [25] France, [26, 27], Japan [28] and other parts of world [29]. In recent development, frequency modulated continuous wave (FMCW) [30,31], was developed at University of Hamburg. In communication of signal, the medium changes to different environmental condition. While communication of signal over water medium, the complex relative dielectric parameter is defined as,

$$\varepsilon = \begin{cases} 1 \; at \; atmosphere, \\ 80 + \dfrac{i\sigma}{\varepsilon\vartheta} \; at \; water \end{cases}$$

Where, $\varepsilon = 8.85 \times 10^{-12} \, As/Vm$ is the absolute permittivity of vacuum, σ conductivity, and ϑ angular frequency component. The conductivity of sea water with variation of its salinity is shown in figure 4. The variation of conductivity affects the dielectric parameter and effect the propagating signal.

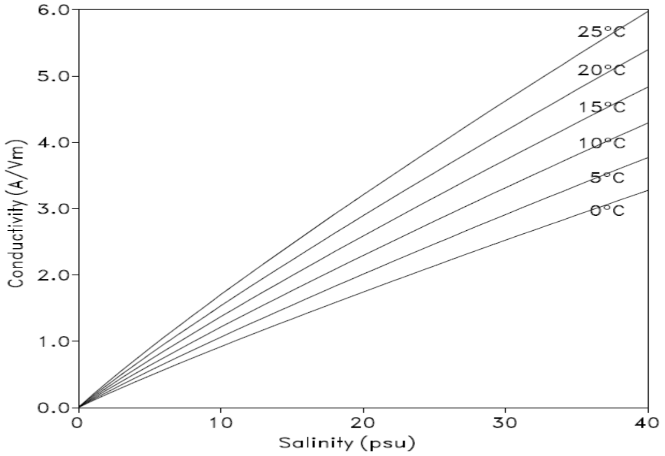


Figure 4. Conductivity over water salinity for different atmospheric temperature

The attenuation of the signal for different operating frequency is presented in figure 5.

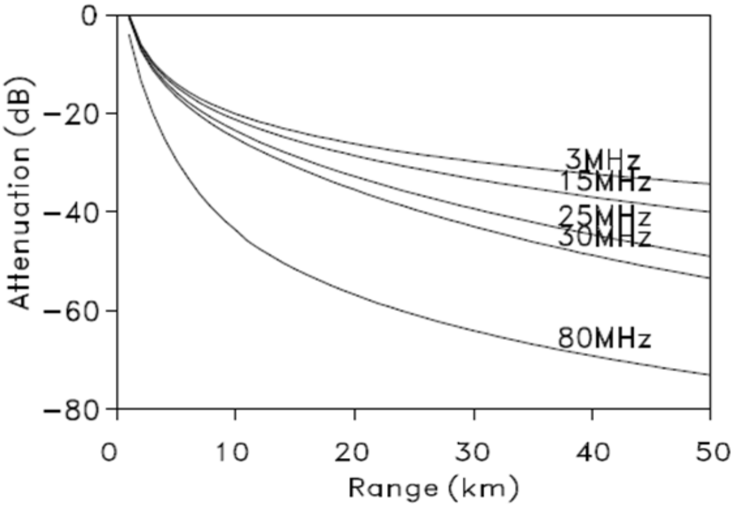


Figure 5. Attenuation for different bands of frequency [33]

The impact of these factors affect the propagation signal and minimizes the detection capability.

III. Signal processing approaches

In detection of target the impact of channel interference and multipath are getting more challenging. In radar signaling different types of signal format is presented in figure 6 below

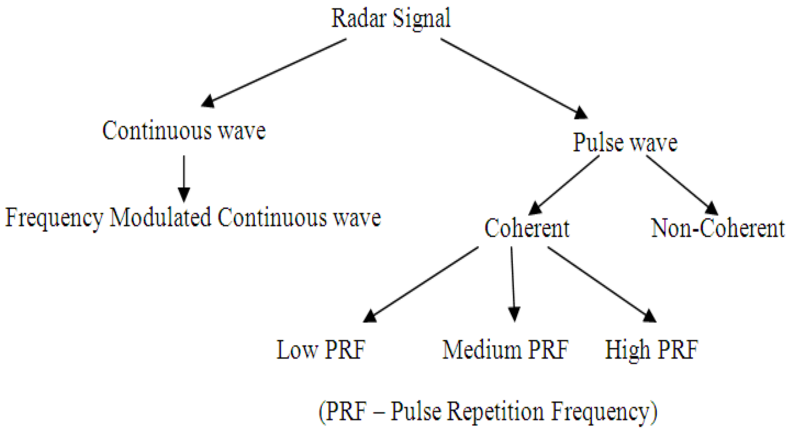
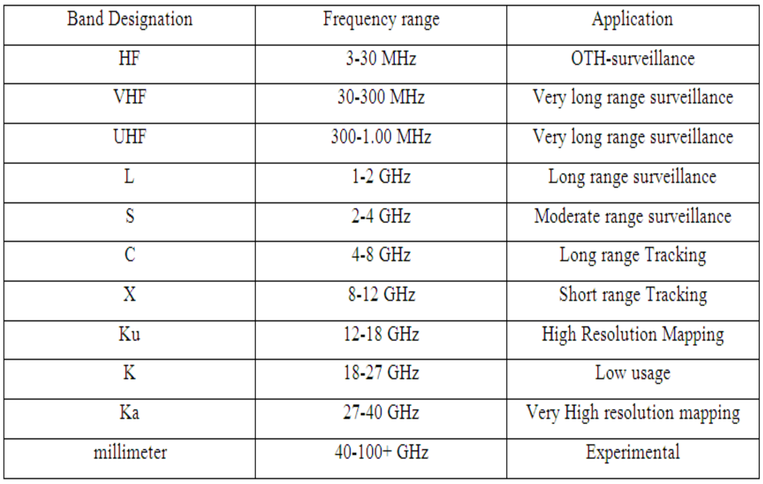


Figure 6. Signaling formats in radar interface

In [34,35] a multi beam approach for target detection based on path separation is proposed. A new low angel tracking approach with target-tracking method using wide range target model is proposed in [36]. The effect of swirling fluctuations in target tracking is analyzed in [37]. With the evolution of new approaches in signal processing, efforts are made in developing new approach to high-resolution modeling for direction of arrival (DOA) under multipath signals [38-40]. The existing approaches of estimation such as multiple signal classification (MUSIC) [41], min-norm approach [42] are optimal in providing better signal to noise ratio (SNR) with loner data monitoring under non correlative environment. The method developed were based on the subspace modeling of the spatial domain. Under low flying objects where echo signals encounter multipath condition, the estimation become difficult. The maximum likelihood (ML) [43] approach which operates on the method of joint probability distribution is used as better solutions under coherent condition compared to MUSIC.

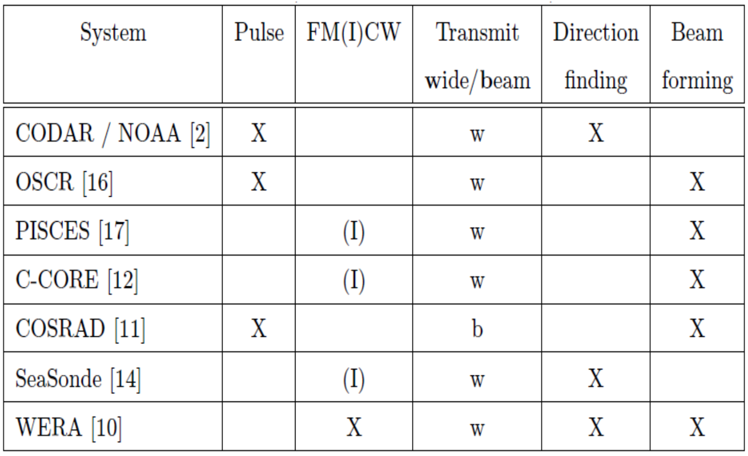
However, the approach has higher computation overhead which restrict its usage in practical applications. For the tracking approach under real time application various approaches were developed in past for low angle radar tracking [44]. Other method using multi frequency tracking is in the proposal [45] for improving tracking performance. In an approach of improving target detection in [46], multiple copies of signals from receivers mounted at different height are used and the variation in echo is computed which is accessed with the measured range to find the height of the flying object. VHF radars [47] are used as a solution to target detection, however, the splitting of beams and multipath effects the utilization performance. In developing new methods, in [48] a phase amplitude comparison approach is presented. The method focus on minimizing the multipath effect by correlating the phase different under different beam split conditions.

Table 1. Observation of frequency range operation with respect to its usage and Band classification



Band Designation	Frequency range	Application
HF	3-30 MHz	OTH-surveillance
VHF	30-300 MHz	Very long range surveillance
UHF	300-1.00 MHz	Very long range surveillance
L	1-2 GHz	Long range surveillance
S	2-4 GHz	Moderate range surveillance
C	4-8 GHz	Long range Tracking
X	8-12 GHz	Short range Tracking
Ku	12-18 GHz	High Resolution Mapping
K	18-27 GHz	Low usage
Ka	27-40 GHz	Very High resolution mapping
millimeter	40-100+ GHz	Experimental

Table 2. Existing systems and their feasibility of parameter detection



System	Pulse	FM(I)CW	Transmit wide/beam	Direction finding	Beam forming
CODAR / NOAA [2]	X		w	X	
OSCR [16]	X		w		X
PISCES [17]		(I)	w		X
C-CORE [12]		(I)	w		X
COSRAD [11]	X		b		X
SeaSonde [14]		(I)	w	X	
WERA [10]		X	w	X	X

In the estimation of accurate target detection, multi-receiver interferometric is used for very high frequency (VHF) radar design [49,50]. Methods such as highest entropy and capon's method [51] are used for power distribution analysis and observing echo signal for coherent radar interface [52-55]. Theoretical analysis of atmospheric radar out come with a technique of "coherent radar imaging" (CRI) [56] used for different layers of atmospheric interfacing, namely the mesosphere, stratosphere, and the troposphere [57-59]. CRI based values are used for practical analysis and applications defining for boundaries of ionosphere applied for HF, VHF and UHF bands [60-66]. The CRI computation derive a range-signal power density wrt., angle of distribution. The direction of arrival (DOA) is estimated as a echo center indicating the tilt angle for non-regular layers [53,64]. Even though the estimation approaches developed in spatial or spectral domains are developed for decision improvement the diversity of interference observed and the link units, the need of new approaches exist for development of more accurate decision making.

IV. Conclusion

Evolution of VHF communication has given a higher opportunity for long range communication and improvement of various applications, such as target detection, navigation, etc. The developments of signal estimation based for different signal processing approaches with different approach of communication were reviewed and presented in this paper. Different approach of target detection and its applications are observed and methods of improving estimation based on signal processing techniques were outlined. The constraints for signal estimation and need of a new faster and accurate decision approaches is highlighted

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