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A Comprehensive Review on Foliage Penetration Radar Systems

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Abstract: **the growing demand for security, safety, and environmental protection at the local, state, and federal levels expose the inadequacy of traditional surveillance and control centers to meet the needs and specifications of contemporary border control systems for homeland protection, where both the land border and the maritime border are expected to be monitored. This is true, for instance, of any land border affected by illegal immigration and/or trafficking, as well as any tiny areas, such as vital infrastructure or military or civilian stations in environments with vegetation, such as forests or jungles. Logistics considerations highly advise having very low low-power devices capable of operating for months or years without maintenance in such a demanding environment. Such an instance ought to be ideal for implementing an Unattended For border control, the Ground Sensors (UGS) network uses foliage penetration (FOPEN) radar. This work aims to outline the fundamental properties and initial findings of a surveillance unattended FOPEN (SUF) radar that can identify moving objects, such as humans or cars, in a forested environment.**

Keywords: **Foliage penetration radar (FOPEN), Ground sensor (UGS), Surveillance unattended FOPEN (SUF).**

1. INTRODUCTION

Radar is an abbreviation for radio detection and ranging. It is mostly used to determine the position, direction, and velocity of an item. Radar is a remote-sensing system that is frequently utilized for both military and civilian surveillance, tracking, and imaging applications [1]. The need for high-powered, economical, and small technology for both military and commercial purposes has led to a renaissance in radar technology. Unmanned aerial vehicles (UAV), and autonomous vehicles, as well as a number of commercial

applications, are examples of cutting-edge technology that rely on solid-state radar, whose fabrication and programming have been modified to meet the requirements of the military and civilian markets of the present [2,3]. In this wide spectrum of demands of radar systems, both military and civilian applications, target recognition and identification in the presence of such dense background clutter are important research subjects. For instance, in contemporary conflict, enemy military targets like tanks, artillery, and other weapon stockpiles can find protection in the forest.

2. BACKGROUND

Early in the 1990s, there is a significant upsurge in the development of foliage penetration radar for military, geoscience, and civilian uses. Starting in 1990[4], as a risk reduction for the development of a more reliable foliage synthetic aperture radar (SAR) system. In the following years, research was started at a number of government institutions, including the NASA jet Propulsion Laboratory, Sweden's Defense Research Establishment, the US Army Research Laboratory, the US Air Force Research Laboratory[5], and the US Naval Air Development Center. The low very high frequency (VHF) band (30 MHz) through the C-band was used for the foliage radar data collection (6 GHz). Instrumentation systems, including standard targets, measurements of the properties of the forest, and receiver calibration techniques, were built based on these experimental results and conclusions to give a description of the one-way losses at various grazing angles [6-8]. Tools for analysis and system simulation were developed concurrently for use in both military and civilian systems. More significantly, it was discovered that polarization was helpful in identifying and ultimately reducing the clutter that impeded the identification of man-made objects. However, these systems and simulation tools are designed based on the laboratory's environmental results and nowadays a lot of research is being carryout in several countries in the real-foliage environment using the existing advanced hardware architectures and signal processing algorithms [9]. Therefore, developing foliage radar to meet several of today's requirements namely target detection, target imaging, personal rescue, forest profile study, animal movement monitoring, weapon detection, intruders monitoring, geographical mapping, and forest remote sensing becomes significant, which is the main object in this research project proposal.

3. SELECTING THE LOCATION FOR THE EXPERIMENT

No location-specific requirements in the research project. The testing and validation trials of the proposed imaging system have to be conducted at the foliage locations which are also available within our campus [10]. Different grades of foliage are situated around our university where we plan to conduct all the experiments operating various static and moving targets within the foliage.

4. CHALLENGES IN FOLIAGE FOR DETECTING TARGETS

Due to the poor detection and high false alarm rates, it is still difficult to detect targets such as people, vehicles, and weapons that are concealed in vegetation. This is primarily due to the following facts: (1) First of all, Target to detect here is a hidden terrorist, Weapon, or any undesired change so as trees and brushes, if the target and trees appear to have the same dielectric frequencies, it will make it hard to differentiate between forest clutters and the desired target [11]. (2) As we know that the surface of forest trees, brushes, and land (soil) land use LU/ land cover LC, are different as in spike, rough, circular surfaces this will lead to having a lot of scattering effect and multipath propagation effects.(3) Foliage is a time-variant changing environment. After some specific time, the Atmosphere or land will change (After rain the soil will change its texture, on sunny days it will be dry, etc.). This all will affect to detection of hidden targets [12, 13].

5. IMPORTANCE OF THE PROPOSED PROJECT IN THE CONTEXT OF THE CURRENT STATUS

Several countries developed their own technology/system for sensing/detecting the targets in the foliage environment. Therefore, building indigenous RF subsystems, antenna assembly, signal processing algorithms, and display devices for our foliage radar becomes significant [14-16]. Further, performing the field trial experiments at our motherland having different jamming environments, land clutters and sea clutters, collecting the data, and tuning the entire system architecture to have a more appropriate foliage target detection and imaging radar system is mandatory [17]. Incorporating the software architecture, cognitive decision-making algorithm and STAP-based signal processing facilitates the radar system to function in a variety of atmospheric circumstances, such as clean air, rain, fog, smoke, haze, and smoke, accomplish high foliage penetration, separate slow-moving target from background tree clutter, and reach a minimum detection range for moving and stationary people and objects. Be small, light, and robust, and localize angle detections to within 10 degrees. Further, imported foliage radar systems are of very high cost i.e., several Cores, they may not be more appropriate for our foliage environment and we need to depend on foreign sources (original manufacturer) for its proper maintenance and operations [18].

6. FOLIAGE RADAR

To the best of our knowledge, no foliage radar systems in our country. We use only day and/or night-vision cameras to take images to detect the intruders (targets) in the foliage environments. This system is very short in range and it requires a clear line of sight and clear atmospheric conditions. An attempt is made with the wireless sensor nodes (cameras, sensors, and Tx/Rx modules) to detect the intruders (targets). In this case, the deployed network system is static at that place and the replacement of the battery for energizing all the noise is a challenging task. Further, deploying a wireless sensor network, moving it to another location, maintenance of network connectivity and coordination of the devices/nodes, and channel equalization are highly complicated operations, particularly in the foliage environment [19-21]. There are few works found in the literature related to foliage radar systems. Only a few countries claim that they have full-fledged foliage radar systems capable of working i.e., detecting the targets from on-ground and airborne platforms. There are few works found in the literature related to foliage radar systems. Only a few countries claim that they have full-fledged foliage radar systems capable of working i.e., detecting the targets from on-ground and airborne platforms [22-25].

7. LITERATURE SURVEY

Jing Liang and Qilian Liang [USA] proposed two algorithms to detect and differentiate the targets present in the more cluttered foliage environment [88]. Ultra-wideband (UWB) radar is used in this work and it is mounted on a moving lift so that the radar system is operated in azimuth and elevation directions so as to collect several aspect-angle data about the target and construct a more accurate image. ShijunZhai and Ting Jiang [China] designed two algorithms (sparse representation i.e., principle component analysis and support vector machine (SVM)) to sense and recognize the weak target in a highly dense foliage environment. The SVM is used to recognize the targets. The experimental results are compared against the classical (differential method, k-nearest neighborhood method, and back propagation neural network technique) algorithms [26]. In this work transmitter and receiver, units are positioned at two opposite ends of a forest and the target is operated in between. Canlin Zhao et al. [USA] proposed an empirical mode decomposition-based approach to UWB radar for sense-through-foliage target detection. In this work, a rake structure consisting of a sensor network distributed in the area of interest in the forest is introduced. Since the sensor network sensors are distributed, it has the capability of detecting even weak targets. However, maintaining such a network, powering the node's batteries, and establishing coordination among the nodes are practically difficult in real surveillance applications. Pengzheng Lei [China] analyzed the statistical prosperities of multiple scattering of clutters in the diverse foliage environment. Amplitude variations of the clutter in line-of-sight (LoS) and non-LoS to the radar is statistically studied [27]. This study is made with ultra-high frequency (UHF) and UWB radar systems. A few models (Kullback-Leibler distance, log-logistic and G^0 and G distribution) are designed based on the experimental data collected at the bush of the National University of Defense technology.

Pengzheng LEI and Xiaotao HUANG [China] developed a radar system to detect robust moving human targets in a foliage environment where more scattering, multipath propagation, and time-varying clutter are observed [28]. A new method called range alignment algorithm using entropy-weighted coherent integration is proposed to suppress the clutter and mitigate the multipath effects. Targets'' complete profile line range, coordinate and Doppler signatures etc., are obtained by processing the radar data using Hough transform. MehrdadSoumekh [USA] presented a method for detecting moving targets embedded in foliage using the monostatic and bistatic SAR from the airborne platform. In his work, two radars are mounted in the aircraft orienting different coordinates in the cross-range domain, however, the range and altitude i.e. slantrange are maintained equally. It is experimentally proved that the two radar-looking methods clearly remove the clutter influence and brings out the targets in the foliage environment. Hans Hellsten, [Sweden] delivered a technical talk on "Foliage penetration radar (FOPEN)" at the International radar symposium India-2017 organized by LRDE and BEL Bangalore [29]. He claimed that their university developed a long-range foliage radar system and it is in function at the Army and Air-force of Sweden. He presented the operation of the foliage radar with some field-acquired result.

8. EXECUTION OF RESEARCH WORK

This section describes the process of the research work, the time schedule of activities giving milestones of execution of proposed foliage radar system design, and plans/suggestions for the utilization of the research outcome of this project [30]. (a) foliage environment and experimentation plan, (b) foliage radar signal propagation phenomenon, (c) significance of STAP algorithm, software defined radar platform and cognitive architecture, (d) proposed STAP assisted software defined cognitive radar system architecture, (e) radar display interface, (f) main scientific specifications of proposed foliage radar system, (g) major procedures of execution/experimentation of proposed radar system, (h) deliverable and expected outcome of this research project and (i) references [31].

9. STAP ALGORITHM

Through this collaboration, we will jointly develop technologyto demonstrate a proto-type foliage radar system. This section describes the overall functions of the proposed foliage radar systems and signal-processing processing algorithms [32-36]. As seen in the literature survey, the radar has to be operated in wideband width i.e., UHF/VHF and slightly above frequency ranges particularly for target imaging. The propriety of radar signal transmission in the foliage environment depends on the type of forest and orientation of the branches to radar. Thus a suitable wide bandwidth antenna assembly has to be designed. A phased array antenna is proposed as a scene to foliage environment. Electronics beam steering approach is proposed in this work to reduce the

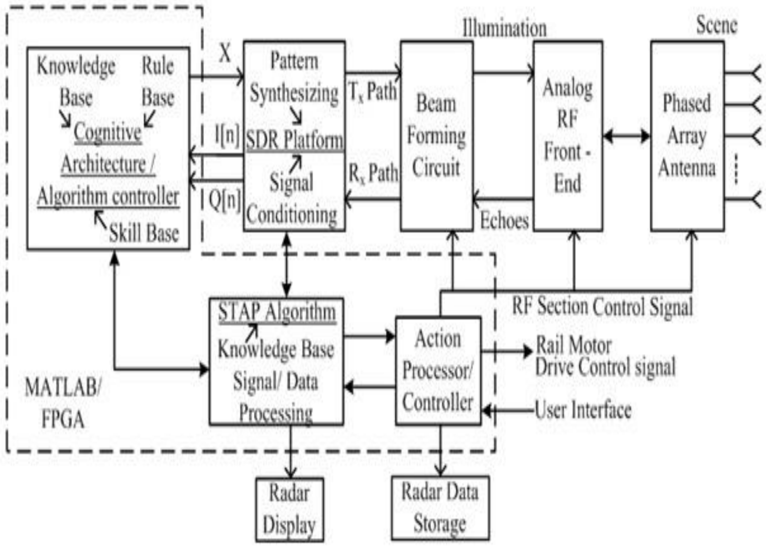


Fig.1 Top-level schematic of proposed STAP-assisted software

system's overall weight as well as to achieve the fine steering of radar beam to realize different types of target imaging: scan, strip-map and spot-light at the later stages. In the beginning, strip-map mode will be followed for target imaging. An optimized beam forming circuit and associated analog RF front-end sections will be developed torealize the transmission of radar signal, beam steering and echo signal reception as shown in Fig. 1. Solid-state RF components are preferred due to their several advantages detailed in [37]. The main components in the RF sections of Tx and Rx chains are power amplifier, variable limiter/attenuator, antenna array, phase shifters, RF filters, TR control switches/modules and LNA. This section is inputted by the software defined radarsection and radar echoes are applied back to the software defined radar platform [38].This radar system will be looked into to see whether there are any stationary or moving man-made targets hiding in the forest. Due to the fact that the picture of a moving target in a reconstructed target image is blended and faint in comparison to the target image of the surrounding stationary foliage, the challenge of detecting moving targets in foliage is extremelychallenging. Additionally, the foliage has a potent coherent signal that, in the frequency domain, overlaps with the target signature becomes difficult to filter out. Therefore, operating radar at different frequencies is mandatory which will be achieved by the software-defined platform. The main function of the software-defined radar platform in this work is pattern synthesizing for beam forming, waveform generation, and signal conditioning. This platform consists of pre-filtering, mixing, analog to digital converter, digital to analog converter, baseband pre-processor, and I&Q signal generator. All these operations happen in the digital domain at greater resolutions and can be driven by the software. This platform is a fully digital front-end for both Tx and Rx chains, thus, it reduces the requirements of several RF components in the analog front-end section, hence, the overall system volume drastically comes down. Further, the baseband processing in this platform performs the waveform design, PRF selection, bandwidth selection, and center frequency selection by the driver software without any change in the physical architecture/structure [39-42]. The inputs (X) [refer Fig. 1] to this platform is given by the cognitive architecture which processes the outputs ([I & Q] and even the raw data) of this platform.

10. MATHEMATICAL ANALYSIS OF FOLIAGE TARGET SCENARIO

(a) IMPORTANCE OF DETECTING A TARGET IN FOLIAGE

A scenario of static and moving targets distributed in the foliage environment is shown in Fig. 2. The identification of foliage targets is crucial for both the elimination of potential hostile enemy activities and the rescue of people in case of an emergency in the forest [43]. Target detection is primarily made challenging by the vegetation environment's non-stationary character. The multi-path propagation/scattering effects in the foliage environment further dominate the received echoes holding the target information, despite the fact that background foliage clutter is dynamic and non-impulsive. Our objective in this effort is to make the target visible despite the dense background plant clutter using the proposed foliage radar system. The proposed radar system will initially be mounded on the ground and used to detect static and moving targets of different kinds i.e., standard known radar cross-section (RCS) targets, personals, animals and weapon caches, etc. Once the radar system detection performance is validated/confirmed, then, it will be mounded on the moving gimbal platform which can travel on the rail system as shown in Fig. 2. Movement of the radar platform will be controlled by a high angular resolution stepper motor system. With this movement, radar synthetic aperture data will be collected at every angle, and then SAR images will be formed for different multiple targets to accurately detect and classify them. In the literature, most of the foliage radar systems are operated with a narrowband signal, within 100MHz and 6GHz, to analyze the foliage attenuation profile, and backscatter statistics, detect the target, and construct the SAR images [44]. The good penetration and high-range resolution ability of UWB radar make it more suitable than narrow-band radar for the purpose of target detection. The standard deviation (std)in the phase error, as determined throughout a series of collection path angles of 30°, 45°, and 60°, is depicted on the graph in Fig. 3. Three frequencies' phase errors: UHF, L-band, and C-band are indicated in Fig. 3 for both horizontal and vertical polarizations [45].

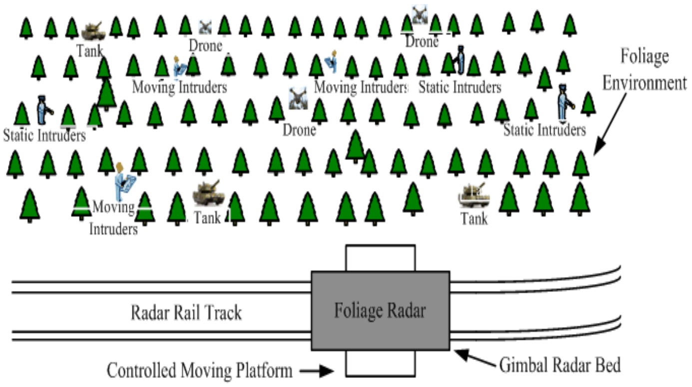


Fig. 2 a scenario of foliage threat environment and layout of on-ground SAR data collectionmechanism

The phase perturbation decreased as the wavelength grew longer. In comparison to the L and C bands, the UHF had substantially reduced phase inaccuracy.Phase scattering in the UHF and L bands would support lower levels of integrated side lobes and waveform resolution than in the C band. Due to the fact that both polarized electromagnetic waves originate from vertical tree trunks, horizontal polarization phase scattering was often smaller than vertical in all of the phase perturbation tests. When compared to the branches, which correspond to the shorter signal wavelength at the c band the sides of the tree contribute more to the scattering [46]. The double bounce phenomena will occur for both horizontal and vertical polarizations, although vertically polarized energy will reach the ground and interact with the treeless strongly.

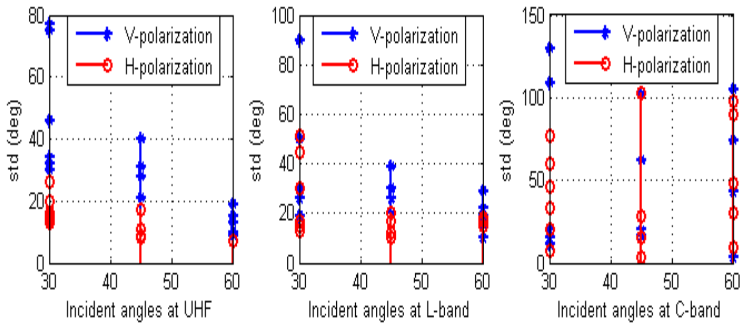


Fig. 3 Phase perturbation versus frequency and incident angles

A powerful single bounce from the ground-tree contact serves as an illustration of horizontal polarization. The return from a side or top hat over a conducting ground plane most closely resembles this, and it also exhibits similar properties at different azimuth-look angles. Finally, depending on the size and placement of the main branches, the tops of the trees and branches spread randomly to the radar. The leaves produce a phase and random variation but have little impact on the major polarization returns for low UHF and VHF. Therefore, developing an indigenous foliage radar system to characterize our motherland foliage environment to have more accurate target detection, imaging and classification are most important [47].

(B) FOLIAGEPENETRATION,SCATTERING,ATTENUATION, AND CLUTTER-MOTION PHENOMENA

The radar illuminates the target region in a straight line with an interpulse spacing in the rail direction. This causes it to generate the cross-range resolution at point P on the target using a synthetic aperture length L and an aperture subtended by an angle. During the data collection, there will be an amplitude and phase disturbance of the radar propagation between the radar and point P at each incidence angle [48-52]. The coherency of the Tx and Rx signals, Doppler properties, SAR processing, and target classifications in the foliage radar systems are all impacted by the forest biomass's amplitude and phase scattering. Targets near and below the forest canopy are affected by the signal-to-clutter evaluations of foliage as a function of frequency, grazing angle, polarisation, and clutter backscattering. Radar evaluates a return signal based on wave propagation and system design elements. The signal-to-noise ratio (S/N) of the radar at range R for a single pulse is given by eqn(1)

$$\frac{S}{N} = \frac{P_T G_T A_R \sigma}{(4\pi)^2 R^4 k T_0 B F_n L_T} \qquad (1)$$

where PT denotes the maximum output power of the transmitter, GT denotes the gain of the transmitter, which is commonly expressed as GT = 4 AT/2, AT denotes the signal wavelength, AR denotes the area of the receiver (equivalent to the transmit area AT), kT0 denotes the radar cross-section, B denotes the signal bandwidth, Fn denotes the receiver's noise figure, and LT denotes the total loss from the transmitter to the P and back. The S/N is increased roughly by the ratio between the compressed pulse length o and the original pulse length 1, as the coded pulse boosts average power [51]. A SAR system's S/N is further improved by the coherent integration of the quantity of received pulses. The platform's velocity (VP) and pulse transmission frequency provide an approximation of the number of pulses recorded during the SAR collection (PRF).A S/N improvement factor (IF) can therefore be generally approximated asin eqn (2)

$$IF = \left(\frac{\tau_1}{\tau_0}\right)\frac{PRFL}{v_p} (2)$$

Where L is the synthetic aperture length. However, in ultra-wideband (UWB) SAR When a synthetic aperture length L is formed, the velocity of the radar platform and PRF can change to obtain the necessary cross-range resolution. δ_{AZ},which can beapproximated by [52]

$$L = \frac{R\lambda}{2\delta_{AZ}} \qquad (3)$$

Wide-angle data collection with its range of slant variations can be accommodated by a longer effective SAR length, which helps create a SAR image with higher resolution. When the target is hidden by a tree, the RCS is defined as follows $\sigma = \sigma_0 \delta R \delta CR \sin(\varphi)$ where surface reflectivity σ0, range resolution δR, cross-range resolution δCR, incidence angle φ, and scattering cell [53-56]. The clutter-to-noise ratio (C/N) can becalculated by replacing these parameters and coherent integration improvement relationships in eqn (1).

$$\left(\frac{C}{N}\right)_{area} = \frac{P_{av}}{8\pi}\frac{A_T^2 \sigma_0 \delta_R}{k T_0 F_n L_T R^3 \lambda}\frac{\sin(\varphi)}{v_p} \qquad (4)$$

Many of these concepts, which are used to describe how foliage spreads, must first be defined by data collection, followed by calibration using known targets in the environment. The radar range equation is transformed into when a discrete target with RCS σT is measured [57].

$$\frac{S}{N} = \frac{P_{av}}{8\pi}\frac{A_T^2}{k T_0 F_n L_T R \lambda}\frac{\sigma_T \delta_R}{v_a \delta_{CR}} \qquad (5)$$

The return from the radar will consist of both the target and any clutter at the same point when it sees a calibration target with a known RCS of σT. When distributed clutter is present at the target point, the point scattered signal-to-clutter ratio (S/C) is given by[58]

$$\frac{S}{C} = \frac{\sigma_T}{\sigma_0 \delta_{CR} \delta_R \sin(\varphi) L_{fol}} \qquad (6)$$

Where σ_0 is background clutter. The introduction ofL_{fol}in the above equation is to include the foliage loss. The backscatter coefficient for uniform clutter areas in the image can be calculated from the measured image response of the known reference reflector. The outcomes are similar to those attained using the predicted peak value. Return from clutter combined with the target as a whole will make up the entire return [59].

$$S_m = S_T + S_C = S_T \left(1 + \left|\frac{S_C}{S_T}\right| e^{j\varphi}\right) \quad (7)$$

whereS$_m$ is the target and clutter contributions are represented by ST and SC, respectively, and the complex radar return. A mixture proportional to the overall return makes up the measured RCS σm [60]. Providing the radar is calibrated radio metrically, then

$$\sigma_m = |S_T|^2 \left(1 + \frac{|S_C|^2}{|S_T|^2} + 2\frac{|S_C|}{|S_T|}\cos(\varphi)\right) \quad (8)$$

After that, the calibration error will be contained by the boundaries.

$$\frac{\sigma_m - \sigma_T}{\sigma_T} = \frac{\sigma_C}{\sigma_T} \pm 2\sqrt{\frac{\sigma_C}{\sigma_T}} \quad (9)$$

The error limitations on a decibel scale will be provided by

$$\sigma_e(dB) = 10\log(1 + \varepsilon_{TC}^2 \pm 2\varepsilon_{TC}) \quad (10)$$

Where εTC = (σC/σT) represents the relative inaccuracy between the calibration target and the measured clutter. Numerous elements combine to cause scattering in a forest environment, but polarized returns of the radiated wave and the wave propagation process in various scattering environments are the key ones [61-66]. The analyses of scattering data, which are obtained from the clutter backscatter magnitude statistics, i.e., the mean (m) and standard deviation (sd), as

$$f(x) = \frac{1}{\sigma x\sqrt{2\pi}} e^{\left[-\frac{(\ln x - \mu)^2}{2\sigma^2}\right]} \quad (11)$$

Where ln(x) is natural log of the scattering cross section,$\mu=0.5[2\ln(m)-\sigma^2]$ and $\sigma^2= \ln[(sd)^2/m^2+1]$. A two-parameter model for polarization and forest type (single or double canopy) was built using the results of a statistical analysis of the median two-way foliage loss versus grazing angle and frequency as their inputs [67].

$$L_{2-way} = \frac{(-\alpha_F)(f_c{}^{\beta f})}{\sin(\gamma_g)} \quad (12)$$

Where α_F is the foliage attenuation scalar factor, β_F is the foliage radar center frequency exponential factor and γ_g is the grazing angle to the local clutter patch. Billingsley showed that a reasonable model for the windblown clutter spectrum probability density function P(vc) would be a delta-function term plus an exponential term as [68].

$$P(v_c) = \frac{r}{1+r}\delta(v_c) + \frac{1}{1+r}\frac{\beta}{2}e^{(-\beta|v_c|)} \quad (13)$$

where r is the ratio of DC to AC power, is the form parameter of the exponential spectrum, and $\delta(v_c)$ is the Dirac delta function centered at zero-Doppler v_c is the velocity of clutter Doppler in meters per second. Billingsley created empirical models for r and β based on substantial data that included differences in the terrain type and seasonal variations as [69-71].

$$r_{dB} = 63.2 - 12.1log_{10}(f_{MHz}) - 15.5log_{10}(W_{mph})(14)$$

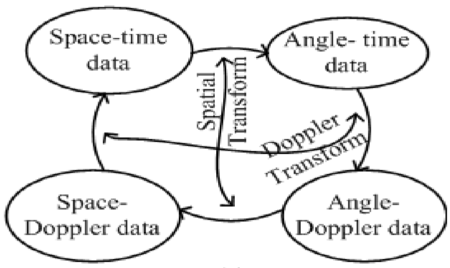
Where f_{MHz} is radar frequency and w_{mph} is the wind speed. For situations ranging from light air to gale-force winds, the exponential form parameter is β depending on the wind speed.

(C) PROPOSED SYSTEM ARCHITECTURE DESIGN AND DESCRIPTIONS

This section describes the overall functions of the proposed foliage radar systems and associated signal-processing algorithms. As seen above, the radar has to be operated in wideband width i.e., UHF/VHF and even above frequency ranges, particularly in SAR imaging; since, the signal has to penetrate through foliage and obtain the SAR signature of concealed targets. The propriety of radar signal transmission in the foliage environment depends on the type of forest and the orientation of the branches to radar [72-75]. Thus a suitable wide bandwidth antenna assembly has to be designed. A phased array antenna is proposed as a scene to foliage environment. An electronic beam steering approach is proposed in this work to reduce the system overall weight as well as to achieve the fine steering of the radar beam to realize different types of SAR imaging: scan, strip-map and spot-light at later stage. In the beginning, strip-map SAR mode will be followed for target imaging. An optimized beam-forming circuit and associated analog RF front-end sections will be developed to realize the radar illumination signal transmission, beam steering and echo signal reception as shown in Fig. 4. Solid-state RF components are preferred due to their several advantages [xx]. The main components in the RF sections of Tx and Rx chains are power amplifier, variable limiter/attenuator, antenna array, phase shifters, RF filters, TR control switches/modules and LNA [76-80]. This section is inputted by the software defined radar section and radar echoes are applied back to the software defined radar platform.

This radar system will be the search for fixed and moving man-made targets concealed by greenery was examined. Finding moving targets amid dense vegetation is a challenging endeavor. This is because, in a reconstructed SAR image, the image of a moving target is combined and weak in comparison to the SAR image of the nearby stationary foliage [81]. Additionally, the foliage has a potent coherent signal that, in the frequency domain, overlaps with the target signature becomes difficult to filter out. Therefore, operating radar at different frequencies is mandatory which is achieved by the software-defined platform. The main function of the software-defined radar platform in this work is pattern synthesizing for beam forming and waveform generation and signal conditioning. This platform consists of pre-filtering, mixing, analog to digital converter, digital to analog converter, baseband pre-processor, and I&Q signal generator. All these operations happen in the digital domain at greater resolutions and can be driven by the software. This platform is a fully digital front-end for both Tx and Rx chains, thus, it reduces the requirements of several RF components in the analog front-end section, hence, the overall system volume drastically comes down. Further, the baseband processing in this platform is the waveform design, PRF selection, bandwidth selection, and center frequency selection by the driver software without any change in the physical architecture/structure. The input (X) to this platform is given by the cognitive architecture which processes the outputs (I[n] & Q[n] and even the raw data) of this platform [82].

The cognitive radar architecture mainly has three layers planning model, task scheduling model, and signal generation model at the Tx chain, feature formation model, recognition model and identification model at the Rx chain, and task association and decision of task concerning the goals as the center models. This architecture process the radar echoes based on its knowledge base, rule base, and skill base to identify/recognize the target from the clutter influence and decide the subsequent radar waveform for transmission. This section performs the process of data acquisition, feature extraction, target calcification, training/testing data sequence generation, decision making, CFAR thresholding, beam forming weight computations, maintenance of range/Doppler/azimuth trajectory record, and STAP weight values computation



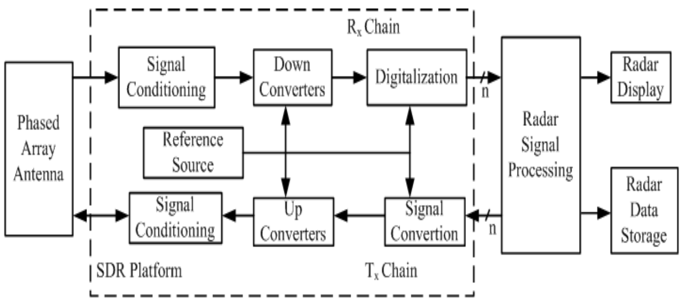


Fig. 4 Top-level schematic of proposed STAP assisted software-defined cognitive foliage radar system

However, this cognitive section works in association with the STAP algorithm as shown in Fig. 4. The STAP algorithm is responsible for several knowledge-based signal/data processing stages including Doppler processing, range compensation, clutter, and jammer cancellation, Doppler compensation, range-velocity mapping, and micro-Doppler signature extraction, etc. To remove intense interference coming from a certain angle, such as side lobe jamming, adaptive array processing was created [83].

11. FUTURE SCOPE

Future technology allows us to identify aerial objects like drones and birds. A change detection system that compares a fresh image to an older imageit automatically detect an event (change detected in the images) if a vehicle enters a resurveyed forest area without the need for a human interface we can detect and classify the targets. By adding these techniques in the future we will get 1. High-range automatic and continuous detection and tracking 2. Continuous operation no matter the weather [84-87].

12. CONCLUSION

Because moving objects induce a Doppler shift in the received echoes, moving objects are frequently detected using a frequency-domain approach, also known as Doppler processing. Lower working frequencies have been found to be less sensitive to minute motions than higher working frequencies. The higher frequency of the radar system must be altered in situations when there is foliage penetration, though, in order to detect a moving target because energy attenuation through the bushes and leaves increases with rising frequency. However, because of the low operating frequency, penetration loss, and small motions, the frequency-domain motion detection method is almost never effective.

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