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MIMO-OTH RADAR: SIGNAL MODEL FOR ARBITRARY PLACEMENT AND SIGNALS WITH NON-POINT TARGETS

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ABSTRACT

Multipath propagation is a fact of life in any terrestrial radio scenario. While the direct or line of sight path is normally the main wanted signal, a radio receiver will receive many signals resulting from the signal taking a large number of different paths. These paths may be the result of reflections from buildings, mountains or other reflective surfaces including water, etc. that may be adjacent to the main path.Here developing the received signal model for a non-point target for multiple input multiple output skywave over-the-horizon (MIMO-OTH) radar. The received signal model is designed with the help of ionospheric state. Initialize the number of propagation paths between a radar antenna and the target center and the correlation between reflection coefficients. By varying the antenna positions and signal frequencies can change the resultant from highly correlated reflection coefficients to virtually uncorrelated reflection coefficients. Both are occurred at the same paths. There are separated conditions are applied for both highly correlated reflection coefficients and virtually uncorrelated reflection coefficients.For solving target detection problem achieved with the proposed model. These process carried under the assumptions of orthogonal transmitted signals and complex Gaussian clutter-plus-noise. The detection performance is performed under the diversity gain of target detection using MIMO-OTH radar is bounded by $\min\{MN, \sum_{m=1}^{M} L_m\}$. Finally achieved the above mentioned bound when the re flection coefficients are mutually independent.

I.INTRODUCTION:

Skywave over-the-horizon (OTH) radar employs ionospheric reflection of signals to detect targets beyond visual range. The performance of the OTH radar system relies heavily on the state of the ionosphere. The commonly used models for describing the ionospheric state usually divide the ionosphere into several layers. These models include the international reference ionosphere (IRI) model [1], the Chapman ionosphere model [2], and the multi-quasi-parabolic (MQP) ionospheric model [3]. In this paper, one of the most accepted ionospheric models, the MQP model, will be incorporated in the received signal model to describe the effects of the ionosphere on the subsequent signal processing of a multiple-input multiple-output (MIMO) radar-based [4]–[13] OTH radar system. In OTH radar systems, transmit signals with certain frequencies can impinge on a target after reflection by different ionospheric layers at different heights. Further, signals which bounce off from the target can reach a receiver after reflection by different ionospheric layers at different heights as well. These factors lead to multiple propagation paths, which is called the multipath ionospheric propagation (MIP) phenomenon. When designing OTH radar systems, one typically attempts to eliminate MIP since it is perceived this may simplify system design in OTH radar. In some cases, it appears it is possible to eliminate the MIP [14], [15]. However, there are cases where it may be hard to eliminate the MIP. For example, consider the case where the ionospheric layer E and layer F2 exist, a target is located at (1000, 0) km, and the elevation angle ranges from 15 to 45 degree. It can be shown that when the available frequency band is in 15.4 to 22.7 MHz, possibly because the other allowable frequencies have been occupied by some users, the number of multipaths must be greater than one, hence one cannot eliminate the MIP. In fact as we change the frequency over this band the number of multiple paths changes between 2, 3 and 4. In [16] it was noted that the presence of multipath propagation can lead to improved detection performance in conventional OTH radar systems. In this paper, we consider the case where the MIP cannot be perfectly eliminated and study the impact of any remaining MIP.

II.LITERATURE SURVEY:

Title 1: Sydney chapman on the layering of the atmosphere: Conceptual unity and the modelling of the ionosphere

Broadband wireless sits at the confrere communications industry in recent years. Both wireless and broadband have on their effluence of two of the most remarkable growth stories of the own enjoyed rapid mass-market adoption. Wireless mobile services grew from 11 million subscribers worldwide in 1990 to more than 2 billion in 2005. During the same period, the Internet grew from being a curious academic tool to having about a billion users. This staggering growth of the Internet is driving demand for higher-speed Internet-access services, leading to a parallel growth in broadband adoption.

Advantages: faster and easier deployment and revenue realization, lower operational costs for network maintenance.

Disadvantages: a null is placed in the direction of the interferers, so the antenna gain is not maximized at the direction of the desired user.

Title 2: Performance of MIMO radar with angular diversity under swerling scattering model

A software Defined Radio (SDR) device employs a reconfigurable hardware (Universal Software Radio Peripheral-USRP) that may be programmed over-the-air or software (GNU Radio) to function under different Wireless standards. This paper analyzes the effect of various

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parameters such as channel noise, frequency offset, timing offset, timing beta, FLL (Frequency Lock Loop) bandwidth, Costas loop (phase) bandwidth, filter roll off factor and multiply const on OFDM signal in WiMAX physical layer with concatenated coding using SDR test bed. Concatenated coding is performed by suggesting RM coder and Convolutional coders as inner code and outer codes respectively.

Advantages: The most obvious benefit is the reduction in complexity and cost because of less hardware usage

Disadvantages: There is no provision to "flush" the encoder.

Title3: CSSF MIMO Radar: Compressive-sensing and step-frequency based MIMO radar

The use of millimeter-wave frequencies is seen as a strong candidate for realizing future, very high data-rate radio systems. Millimeter-wave frequencies offer large bandwidths for short range indoor communications and outdoor point-to-point radio links. In this thesis, millimeter wave antenna solutions and radio wave propagation channels are studied. One of the key questions that needs to be answered before millimeter-wave devices can be produced profitably in large quantities is how to realize a low-cost antenna that is efficient and can be integrated with other parts of the transceiver.

Advantages: significant cost reduction and improved design flexibility due to the absence of the inter-connection between the MMIC and the antenna.

Disadvantages: a low total efficiency, which is typically only 10 % at 60 GHz and low gain

Title 4: Target localization and tracking in noncoherent multiple-input multiple-output radar systems

Orthogonal frequency division multiplexing (OFDM) provides an effective and low complexity means of eliminating inter symbol interference for transmission over frequency selective fading channels. This technique has received a lot of interest in mobile communication research as the radio channel is usually frequency selective and time variant. In OFDM system, modulation may be coherent or differential. Channel state information (CSI) is required for the OFDM receiver to perform coherent detection or diversity combining, if multiple transmit and receive antennas are deployed. In practice, CSI can be reliably estimated at the receiver by transmitting pilots along with data symbols. Both data and pilot carriers in one block of OFDM symbols are used. Pilot carriers are used to estimate the channel impulse response. The estimated channel can be used to get back the data sent by transmitter certainly with some error. In the simulation, 1024 number of carriers in one OFDM block is used, in which one fourth are used for pilot carriers and rest are of data carriers.

Advantages: The major advantage of OFDM lies in processing frequency-

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selective channels as multiple flat-fading sub-channels.

Disadvantages: high peak-to-average-power ratio (PAPR), bit error rate (BER) and high sensitivity to carrier frequency offset (CFO).

III.EXISTING SYSTEM:

As over-the-horizon radars use ionosphere reflection to detect and track targets, they are faced with a possible appearance of multipaths and difficulties to estimate the target ground location. To solve these problems we propose to use a ionosphere model called multi-quasi-parabolic (MQP) model. Introducing the coefficients of the MQP model into a target tracking algorithm leads to nonlinear evolution and measurement equations. Furthermore we only have estimation, through ionosphere measurements, of these parameters values. To take into account MQP parameters in a target tracking algorithm, we propose two different approaches built on the same algorithm: the unscented Kalman filter. In the first approach, we use a joint unscented Kalman filter and in the second one we use an unscented particle filter applied on both target state space and MQP parameters space (we could call this a joint unscented particle filter).

Disadvantage:

That horizontal gradients in the electron density and the effect of the geomagnetic field cannot be included in the determination of the ray path characteristics

IV.PROPOSED SYSTEM:

Multipath ionospheric propagation (MIP), a typical phenomenon the sky wave over-the-horizon (OTH) radar may encounter, is often viewed as an annoying factor to be eliminated in the traditional OTH radars. In this paper, we consider multiple-input multiple-output sky wave over-the-horizon (MIMO-OTH) radar with closely spaced antennas.Taking into account the existence of multipath ionospheric propagation (MIP), this paper develops the received signal model for a non-point target for multiple-input multiple-output skywave over-the-horizon (MIMO-OTH) radar for the first time. The model describes the ionospheric state, the number of propagation paths between a radar antenna and the target center, as well as the statistics of the reflection coefficients. It is shown that varying system parameters, such as antenna positions and signal frequencies, can result in causing the model to change from a case with highly correlated reflection coefficients to a case with virtually uncorrelated reflection coefficients.

V.MODULES:

- System Model
- Correlation Between Reflection Coefficients
- Target Detection
- Performance Analysis

5.1.System Model:

There are M transmit antenna and N receive antenna.

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m= 1,2,…M and is located at $(x_{\mathrm{T}m}, y_{\mathrm{T}m})$.

The base band signal is transmitted from $\sqrt{E/M}s_m(t)$.

nth receive antenna is located at $(x_{\mathrm{R}n}, y_{\mathrm{R}n})$ target is located at (x_0, y_0)

the reflection coefficient of the scatterer located at $(x + x_0, y + y_0)$ The reflection coefficient $U(x, y)$ is assumed to be a zero-mean complex random variable such that $\mathbb{E}\{U(\gamma,\beta)U^*(\eta,\varsigma)\} = [1/(\Delta x \Delta y)]\delta(\gamma,\eta)\delta(\beta,\varsigma)$ if $\gamma,\beta,\eta,\varsigma$ are all in the region where the scatterers are located.thegroundrange ,

$$R_{\mathrm{G}m} = 2z_0^2 \cos\vartheta_m[I_1(z_0, z_b; z_0, \vartheta_m) + I_1(z_b, z_{\mathrm{F}m}; z_0, \vartheta_m)],$$

where the generic integral $I_1(a, b; p, q)$ is defined as

$$I_1(a, b; p, q) \triangleq \int_a^b \frac{dz}{z\sqrt{z^2\mu_m^2(z) - p^2\cos q}},$$

z_0 is the earth radius, $z_b = z_0 + h_b$, h_b is the height at the base of the ionospheric layer, $z_{\mathrm{F}m} = z_0 + \hbar_m$,

$$\mu_m(z) = \sqrt{1 - 80.6N_e(z)/f_{cm}^2}$$

is the index of re flection with the electron density at z being,

$$N_e(z) = \begin{cases} N_m\left[1 \pm \left(\frac{z - z_m}{p_m}\right)^2\left(\frac{z_b}{z}\right)^2\right], & z_b < z < \frac{z_m z_b}{z_b - p_m} \\ 0, & \text{otherwise} \end{cases}$$

the received signal at the th receive antenna due to the transmission of the the transmitter and the re flection of the target is a superposition of the signals,

$$r_{mn}(t) = \sum_{l=1}^{L_{mn}} \sum_{k=1}^{K_m} r_{mnkl}(t)$$

where $r_{mnkl}(t)$ denotes the received signal from the kth forward propagation path.

lth backward propagation path,

$$r_{mnkl}(t) = \sqrt{\frac{E}{M}} \int_{x_0 - \frac{\Delta x}{2}}^{x_0 + \frac{\Delta x}{2}} \int_{y_0 - \frac{\Delta y}{2}}^{y_0 + \frac{\Delta y}{2}} s_m[t - \tau_{\mathrm{F}mk}(x_{\mathrm{T}m}, y_{\mathrm{T}m}, \gamma, \beta) - \tau_{\mathrm{B}mnl}(x_{\mathrm{R}n}, y_{\mathrm{R}n}, \gamma, \beta)] \times e^{j2\pi f_{mnkl}t} e^{j\varphi_{mnkl}} U(\gamma - x_0, \beta - y_0) d\beta d\gamma. \quad (6)$$

where $\tau_{\mathrm{F}mk}(x_{\mathrm{T}m}, y_{\mathrm{T}m}, \gamma, \beta)$ represents the time delayof the signal propagating from the mth transmitter tothe scatterer located at (γ, β) via the kth forward path.

$\tau_{\mathrm{B}mnl}(x_{\mathrm{R}n}, y_{\mathrm{R}n}, \gamma, \beta)$ represents the time delay of the mth transmitted signal propagating from the scatterer at to the nth receiver (γ, β) via the lth backward path.

f_{mnkl} denotes the Doppler frequency.

φ_{mnkl} represents the effect of the phase perturbation.

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phase term $s_m[t - \tau_{Fmk}(x_{Tm}, y_{Tm}, \gamma, \beta) - \tau_{Bmnl}(x_{Rn}, y_{Rn}, \gamma, \beta)]$

thetime,delays

$$\tau_{Fmk}(x_{Tm}, y_{Tm}, \gamma, \beta) = \frac{2}{c}[I_2(z_0, z_b; z_0, \vartheta_{mk}) + I_2(z_b, z_{Fmk}; z_0, \vartheta_{mk})]$$

and

$$\tau_{Bmnl}(x_{Rn}, y_{Rn}, \gamma, \beta) = \frac{2}{c}[I_2(z_0, z_b; z_0, \theta_{mnl}) + I_2(z_b, z_{Bmnl}; z_0, \theta_{mnl})],$$

where c is the light speed and the generic integral $I_2(a, b; p, q)$ is defined as,

$$I_2(a, b; p, q) \triangleq \int_a^b \frac{zdz}{\sqrt{z^2\mu_m^2(z) - p^2\cos q}}.$$

The Doppler shift associated with the $mnkl$ th path is

$$f_{mnkl} = \frac{1}{\lambda_m}[(\cos\vartheta_{mk} + \cos\theta_{mnl})v_x + (\sin\vartheta_{mk} + \sin\theta_{mnl})v_y$$

The signal received at the nth receiver contributed by the mth transmitter through the propagation along the kth forward path and the lth backward path,

$$r_{mnkl}(t) = \sqrt{\frac{E}{M}}\varepsilon_{mnkl}e^{j2\pi f_{mnkl}t}e^{j\varphi_{mnkl}}e^{-j\phi_{mnkl}} s_m(t - \tau_m$$

where $\varepsilon_{mnkl} \sim CN(0, 1)$ represents the equivalent re flection coefficient with standard complex Gaussian distribution,

$$\phi_{mnkl} = 2\pi f_{cm}[\tau_{Fmk}(x_{Tm}, y_{Tm}, x_0, y_0) + \tau_{Bmnl}(x_{Rn}, y_{Rn}, x_0, y_0) - \tau_{mn}]$$

Where,

$$\tau_{mn} = \tau_{Fm1}(x_{Tm}, y_{Tm}, x_0, y_0) + \tau_{Bmn1}(x_{Rn}, y_{Rn}, x_0, y_0),$$

In which $\tau_{Fm1}(x_{Tm}, y_{Tm}, x_0, y_0)$ and $\tau_{Bmn1}(x_{Rn}, y_{Rn}, x_0, y_0)$ denote the reference time delays corresponding to the forward and backward propagation paths respectively.

5.2.Correlation Between Reflection Coefficients:

The correlation between the equivalent reflection coefficients ε_{mnkl} and $\varepsilon_{m'n'k'l'}$ associated with the $mnkl$ th and the $m'n'k'l'$ -th paths,

$$\mathbb{E}\{\varepsilon_{mnkl}\varepsilon^*_{m'n'k'l'}\} = P_x P_y$$ where

$$P_x = \text{sinc}(\pi\Delta x\kappa_x), P_x = \text{sinc}(\pi\Delta y\kappa_y)$$

The two coefficients ε_{mnkl} and $\varepsilon_{m'n'k'l'}$ are approximately uncorrelated.

where

$$\kappa_x \triangleq \frac{(\hbar_{m'k'} + z_0)(x_{Tm'} - x_0)}{\lambda_{m'}\rho_{m'k'}} + \frac{(h_{m'n'l'} + z_0)(x_{Rn'} - x_0)}{\lambda_{m'}\sigma_{m'n'l'}} - \frac{(\hbar_{mk} + z_0)(x_{Tm} - x_0)}{\lambda_m\rho_{mk}} - \frac{(h_{mnl} + z_0)(x_{Rn} - x_0)}{\lambda_m\sigma_{mnl}}$$

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and

$$\kappa_y \triangleq \frac{(\hbar_{m'k'}+z_0)(y_{Tm'}-y_0)}{\lambda_{m'}\rho_{m',k}} + \frac{(h_{m'n'l'}+z_0)(y_{Rn'}-y_0)}{\lambda_{m'}\sigma_{m'n'l'}} - \frac{(\hbar_{mk}+z_0)(y_{Tm}-y_0)}{\lambda_m\rho_{mk}} - \frac{(h_{mnl}+z_0)(y_{Rn}-y_0)}{\lambda_m\sigma_{mnl}},$$

in which λ_m denotes the wavelength of the mth transmitted signal,

$$\rho_{mk} = \left\{\left(4z_0^2 - R_{Dm}^2\right)\left[\left(\hbar_{mk}+z_0\right)^2 + z_0^2 - \left(\hbar_{mk}+z_0\right)\sqrt{4z_0^2 - R_{Dm}^2}\right]\right\}^{1/2},$$

and

$$\sigma_{mnl} = \left\{\left(4z_0^2 - R_{Dn}^2\right)\left[\left(h_{mnl}+z_0\right)^2 + z_0^2 - \left(h_{mnl}+z_0\right)\sqrt{4z_0^2 - R_{Dn}^2}\right]\right\}^{1/2},$$

with $R_{Dm} = [(x_{Tm}-x_0)^2 + (y_{Tm}-y_0)^2]^{1/2}$ and $R_{Dn} = [(x_{Rn}-x_0)^2 + (y_{Rn}-y_0)^2]^{1/2}$.

Correlation Between ε_{mnkl} and $\varepsilon_{mn'kl'}$ for $n \neq n'$

For two signals, $r_{mnkl}(t)$ and $r_{mn'kl'}(t)$, received at different receivers due to the transmission from the same transmitter via the same forward propagation path but different backward propagation paths,

$$|\kappa_x| = \left|\frac{(h_{mn'l'}+z_0)(x_{Rn'}-x_0)}{2\lambda_m h_{mn'l'} z_0} - \frac{(h_{mnl}+z_0)(x_{Rn}-x_0)}{2\lambda_m h_{mnl} z_0}\right|$$

Correlation Between ε_{mnkl} and $\varepsilon_{m'nk'l'}$ for $m \neq m'$

For two signals, ε_{mnkl} and $\varepsilon_{m'nk'l'}$, received at the same receiver due to the transmission from different transmitters via different propagation paths,consider the case where $x_{Tm} \approx x_{Tm'}$, $\hbar_{mk} \approx \hbar_{m'k'}$ and $h_{mnl} \approx h_{m'nl'}$. Thus,

$$|\kappa_x| = \left|\frac{1}{\lambda_m} - \frac{1}{\lambda_{m'}}\right| \left|\frac{(\hbar_{mk}+z_0)(x_{Tm}-x_0)}{2\hbar_{mk} z_0} + \frac{(h_{mnl}+z_0)(x_{Rn}-x_0)}{2h_{mnl} z_0}\right|$$

$$|\kappa_x| = |f_{cm} - f_{cm'}| \left|\frac{(\hbar_{mk}+z_0)(x_{Tm}-x_0)}{2\hbar_{mk} z_0} + \frac{(h_{mnl}+z_0)(x_{Rn}-x_0)}{2h_{mnl} z_0}\right|.$$

Correlation Between ε_{mnkl} and $\varepsilon_{mnk'l'}$ for $k \neq k'$ or $l \neq l'$

For two signals, $r_{mnkl}(t)$ and $r_{mnk'l}(t)$, received at the samereceiver due to the transmission from the same transmitter via the same backward propagation path but different forward propagation path,

$$|\kappa_x| = \left|\frac{(\hbar_{mk'}+z_0)(x_{Tm}-x_0)}{2\lambda_m \hbar_{mk'} z_0} - \frac{(\hbar_{mk}+z_0)(x_{Tm}-x_0)}{2\lambda_m \hbar_{mk} z_0}\right|$$

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$$= \frac{|x_{Tm} - x_0|}{2\lambda_m} \left| \frac{1}{\hbar_{mk'}} - \frac{1}{\hbar_{mk}} \right|.$$

for two signals, $r_{mnkl}(t)$ and $r_{mnk'l}(t)$, received at the same receiver due to the transmission from the same transmitter via the same forward propagation path but different backward propagation propagation paths,

$$|\kappa_x| = \frac{|x_{Rm} - x_0|}{2\lambda_m} \left| \frac{1}{h_{mnl'}} - \frac{}{h_{r}} \right.$$

5.3.Target Detection:

Signal from the mth transmitted signal received at the nth receiver can be expressedas,

$$r_{mn}(t) = \sum_{l=1}^{L_m}\sum_{k=1}^{K_m} r_{mnkl}(t)$$
$$= \sqrt{\frac{E}{M}} \sum_{l=1}^{L_m}\sum_{k=1}^{K_m} \varepsilon_{mkl} e^{j2\pi f_{mkl}t} e^{j\varphi_{mkl}} e^{-j\phi_{m1kl}}$$
$$\times e^{-j(n-1)2\pi f_{cm} d_r \cos\theta_{ml}/c} s_m(t-\tau_m).$$

the received signalto a bank of filters matched to these transmit signals, the output of the matched filter matched to $s_m(t),\ m = 1, \ldots, M$ is,

$$\tilde{r}_{mn} = \int_{-\infty}^{+\infty} r_n(t) s_m^*(t) dt = \sqrt{\frac{E}{M}} \mathbf{a}_{mn}^T \varepsilon_m + w_{r}$$

where

$$\mathbf{a}_{mn} = [a_{mn11}, a_{mn21}, \ldots, a_{mnK_mL_m}]^T,$$
$$a_{mnkl} = e^{j\varphi_{mkl}} e^{-j\phi_{m1kl}} e^{-j(n-1)2\pi f_{cm} d_r \cos\theta_{ml}/c},$$
$$k = 1, \ldots, K_m, \quad l = 1, \ldots, L_m,$$
$$\varepsilon_m = [\varepsilon_{m11}, \varepsilon_{m21}, \ldots, \varepsilon_{mK_mL_m}]^T,$$

The optimal test under the NP criterion is,

$$T = \tilde{\mathbf{r}}^H \mathbf{R}_\mathbf{w}^{-1} \mathbf{A} \mathbf{P}^{-1} \mathbf{A}^H \mathbf{R}_\mathbf{w}^{-1} \tilde{\mathbf{r}} \gtrless_{H_0}^{H_1} \delta,$$

where the threshold δ is determined by the false alarm probability,

$$\mathbf{P} = \frac{E}{M} \mathbf{A}^H \mathbf{R}_\mathbf{w}^{-1} \mathbf{A} + \mathbf{R}^{-1}$$

R is the nonsingularcovariance matrix of the vector ε.

Performance Analysis:

Miss detection probability has been estimated for various SCNR value.

CONCLUSION

MIMO-OTH radar equipped with transmit antennas and receive antennas was considered. Taking into account the existence of MIP, based on the MQP ionospheric model, the received signal model of MIMO-OTH radar has been developed for possible non-point target. The correlation between any two equivalent reflection coefficients has been derived. This correlation was shown to depend on system parameters such as the target size, target position, antenna positions, operating frequencies, ionosphere layer base hight, ionosphere layer semi-thickness, and ionosphere electron density. Conditions for judging whether the reflection coefficients associated with different propagation paths

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are correlated or approximately uncorrelated have been provided. The application of the developed signal model was illustrated by a target detection example. Under the assumptions of orthogonal transmitted signals and complex Gaussian clutter-plus-noise, the optimum detector under the NP criterion has been derived for an example case. The detection performance has been studied. It has been proved that for the studied case, the diversity gain for target detection using MIMO-OTH radar is upper bounded by and this bound can be achieved when the reflection coefficients are mutually independent. This is an interesting finding which indicates that a diversity of can be obtained even when the receive antennas are closely spaced, as long as the total number of backward paths is large enough, which demonstrates the benefits of having the MIP phenomenon.

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