SARSCAT - A Ground Based Scatterometer For Space-Borne SAR Applications

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Abstract - SAR imagine applications are usually carried out by tow ways: the physical/ mathematics models and the measured terrain material microwave signatures. In most of the cases, people like to use the mathematics models since the microwave signature database are not matching the practical case very well. In this paper, we will discuss the reason of the uncertainties provided by these database from the instrument point of view and propose a new ground-based scatterometer, SARSCAT, specially designed for SAR applications.

I. INTRODUCTION

Currently, there are several space-borne synthetic aperture radar operating such as ERS-1, ERS-2, JERS-1 and RADARSAT. They are now providing commercial radar images from the space. From these images, people can extract many unique information which visible and inferred frequency band sensors cannot or has difficulties to provide. However, applications of those radar images are still remain in a low level comparing with visible and inferred images. One of the main reason is that the ground measured terrain microwave signature or spectrum database are not complete. The incomplete is not referring the quantity but the quality of those data.

Historically, the purpose to measure the terrain microwave signature on the ground is to study the mechanism of microwave remote sensing. Therefore most of the measurements are made in the earlier years in 70's and 80's [1]-[3]. Since the purposes are different, with SAR applications, these signature data may not provide required accuracy and measurement conditions. In this paper, we will discuss the differences between the conventional terrain microwave signature measurements and the SAR application measurements and propose a new ground-based scatterometer system as shown in Fig.1, which will most closely represent the SAR measurement conditions.

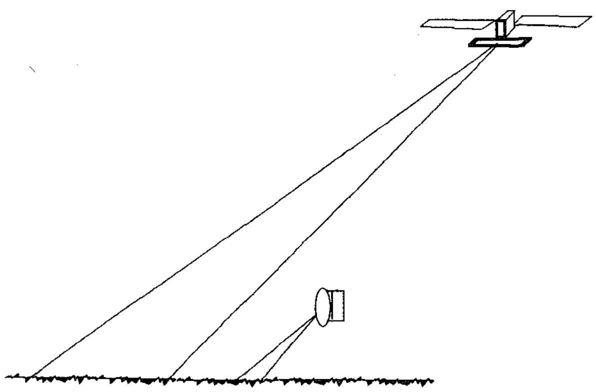

Fig. 1 Space and ground systems

II. GROUND-BASED BACKSCATTERING MEASUREMENTS AND BANDWIDTH CONSIDERATION

Radar measurement is based on the return signal from the object under illumination of the transmit antenna. For remote sensing application, the return signal is not from an single object, but an extended ground area. Therefore it is a continuous extended target. The backscattering signal at the receiving antenna is a coherent summation of the returns from many independent scattering points. It is obviously that a single measurement represent only a particular geometrical relation between the sensor and the ground scattering points. Once the sensor position changed, or the ground objects moved such as the ocean surface, the measurement result will be changed also. For this reason, the only way to get a meaningful measurement result is to

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move either the sensor position or the ground objects to make many independent measurements and calculate the average of them. This is actually what a scatterometer or SAR doing.

The number of independent samples used to calculate the average is important. The more samples are used, the more stable result will be got. In practice, the number of independent samples is always limited. Searching for more stable result with limited samples, many instruments use wide frequency band to compensate the measurement result fluctuations. Typically, a FM-CW system scatterometer may use 1GHz or more bandwidth at C band. However, the terrain react differently at different frequencies. To use wide frequency band will unable us to measure the terrain response at particular interested frequencies. In other words, the measurement results from to instruments with different frequency band are not usually comparable.

Most of existing terrain signature database were measured by FW-CW ground scatterometer system which has wide bandwidth. However the bandwidth of space-borne SAR is less than 100MHz. The measurement results must not the same even if the two instruments measuring the same terrain simultaneously. This is one of the reasons that we propose a new instruments for SAR applications.

III. GROUND PENETRATION AND POWER CONSIDERATIONS

Microwave remote sensing has the advantage to get information penetrate the terrain surface. The depth of the penetration in which the sensor can get the information depends not only on the frequency band, but also the incident power and the receiver sensitivities. Therefore, in order to get the same information as the space-borne SAR, the ground scatterometer for SAR applications must have the same penetration as the SAR does. To verify this, let us consider radar equation first

$$P_{RS} = \frac{P_{TS} G_S^2 \lambda^2 \sigma}{(4\pi)^3 R_S^4} \qquad (1)$$

where P_{RS} and P_{TS} is the space-borne SAR received and transmit power respectively, G_S is the SAR antenna gain and R_S is the distance between the satellite and the coverage center. σ is the ground backscattering coefficient.

For space-borne SAR, suppose P_{TS} is 5.3KW, the returned power at the receiver may vary from -104dBm to -56dBm representing the highest and the lowest σ from the terrain. From (1) we have

$$\sigma = \frac{P_{RS}}{P_{TS}} \frac{(4\pi)^3 R_S^4}{G_S^2 \lambda^2} \qquad (2)$$

Let G_S= 30dB; R_S = 1100km; λ = 0.0566m

$$\sigma = 9.07 \times 10^{23} \frac{P_{RS}}{P_{TS}} \qquad (3)$$

substitute the value for P_{RS} and P_{TS}, got

$$\sigma_h \approx 4.3 \times 10^{11} \qquad \sigma_l \approx 6.8 \times 10^6$$

For a 30dB gain antenna (3°×12°), 45° incident angle, the coverage area may be around 1.8x10^{10} m^2 , therefor we have

$$\sigma_h^o \approx 23.9 \qquad \sigma_l^o \approx 3.8 \times 10^{-4}$$

For ground-based scatterometer, σ_h^o and σ_l^o should remain the same. Suppose a ground system has a 22dB (15°×15°), the coverage of the antenna at a 10 meter platform and incident angle 45° is about 15.3m^2. From (1) we have

$$P_T = \frac{(4\pi)^3 R^4 P_R}{G^2 \lambda^2 \sigma} \qquad (4)$$

$$P_T \approx 1.7 \times 10^8 P_R$$

If the receiver sensitivity is -85dBm, for σ_l^o we have P_T = 0.54mW, or -2.6dBm. For the same transmit power and σ_h^o , P_R = -37dBm, 48dB higher than the case with σ_l^o.

This shows that, it is possible to represent the same penetration as the SAR did by a ground based system. On the other hand, if the output power and the sensitivity of the ground system is too high, it may have more penetration than the SAR does. Consequently it will measure a different terrain spectrum and lead erroneous for SAR applications.

IV. CALIBRATION CONSIDERATIONS

Beside the above considerations on power and bandwidth, a ground-based scatterometer for space-borne SAR applications must has the same polarization as the SAR and it should use the pulse radar system and a single antenna for both transmit and receive.

With such a kind of scatterometer, one should has the possibility to obtain the same backscattering coefficient as the SAR if the scatterometer is calibrated carefully. However, as we have discussed before, if the environment conditions are different between the two measurements, one may still have problem to compare the results. Therefore the best way to calibrate the ground and space platform sensors is to make a simultaneous measurements. By this way, no matter which instrument has calibration inaccuracies, the ground scatterometer measurements will be fully calibrated according to the SAR and its sequential measurements after the simultaneous calibration will be very useful for any application measurements.

The so called simultaneous measurement is actually a quasi-simultaneous measurement. Because the two instruments using the same frequency, a purely simulations measurement will give the ground instruments a lot of interference from the SAR transmit signal. Therefore the best way to do it is to carry out the ground measurement a few minutes before or after the SAR overpass.

V. SYSTEM DESIGN FOR SARSCAT

As it is addressed in Section II, the backscattering measurement is based on the statistics of many independent samples. Furthermore, an single measurement must cover many single scattering points in the illuminated area in order to represent the terrain material. It is proposed that the ground based scatterometer system use a modest resolution antenna. Therefore a 22dB gain reflect antenna is proposed.

A diagram of SARSCAT is shown in Fig. 2. As it is discussed in Section II, SARSCAT must has the same bandwidth as the SAR. This is adjusted be the tow switches in the transmit channel and controled by the pulse generator. The transmit power is controld by CPU through the power amplifier. In the receiving channel, the return wave is amplified and detected directly from RF at 5.3GHz.

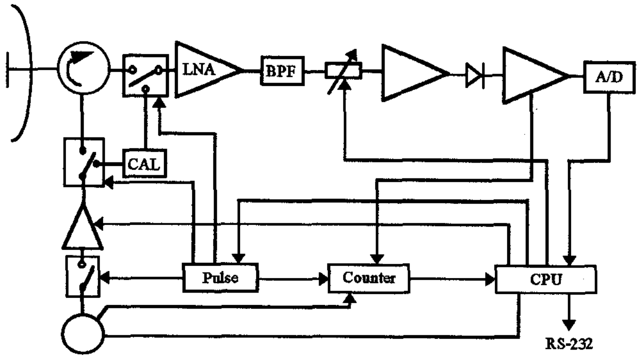

Fig. 2 Proposed SARSCAT design

V. CONCLUSIONS

Existing terrain microwave signature database are not suitable for SAR applications because of bandwidth, power and other considerations. A new ground-based system is then proposed to carry out the terrain microwave signature for space-borne SAR applications. It is shown that the ground-based system could repeat the SAR measurement from every technical aspects including power, bandwidth, calibration, etc. A design case for such a system is proposed.

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