Radio Wave Propagation on the Ice Cap

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氷冠雪上の電波伝播特性

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要旨

1. 目的 万年雪，高圧気泡入氷からできた氷冠域において，雪氷の高周波誘電特性雪，表面の電波の反射吸収特性，比抵抗等を測定することにより，極地方の氷冠内における電波伝播特性の解析，氷冠上にて使用するアンテナの設計，通信回線の設計等のための資料を得ることを目的とし，1.5, 10, 100, 250, 300, 400, 3000 Mc の各周波数毎に，(1) 容量置換法，レッヘル線により，誘電率，誘電体損 (tan δ) を，(2) ハイトパターン法により反射，吸収係数を，コーラウシュブリッジにより比抵抗を測定し，数種のアンテナにより通信を行ない電界強度を測定した．また気温逆転層による 300, 3000 Mc のフェーディング特性，万年雪にまい没したアンテナと空間のアンテナとのインピーダンス，指向性パターン等も測定した．

2. 結果 実測の結果，万年雪および氷冠氷の比誘電率の値は非常に小さく，周波数の増加，密度の減少とともに減少する．誘電体正切特性の値も非常に小さく，周波数の増加とともに激減する．反射係数も HF 帯では小さく，周波数の増加とともに増加する．

従って氷冠の雪氷上で使用するアンテナは表面の雪の比誘電率が1に非常に近いので，雪面上に直接導線を置くだけの非常に簡単なアンテナで，ほぼ自由空間とみなし得る輻射が得られることが解り，秋春の大陸旅行において実証することができた．なお，測定に使用した機器は昭和基地にて製作したため帰国後検定中であり，期日の都合で今回は現在までに得られた較正データのみ中間報告として発表する．

海氷上の電波伝播は VHF 以下の周波数帯では大略海水面と同じ特性を示し，UHF 以上はその表面の状態（氷，雪）の影響が大きい．なお偏波面は氷冠上が水平，海氷上は垂直が良いようであった．

1. Introduction

The Antarctic continent is covered with an ice cap more than 2000 meters in depth. The snow is piled up every year without melting away and is changed to ice, because the downward snow is compressed by the gravitation caused by the piled up snow. The air involved in the snow forms air cells the presser of which increases with the degree of compression, and it becomes to have a quite different nature from an ordinary ice called "ice cap ice" and therefore the density of ice increases with the depth.

Because it is surmised that the electromagnetic wave propagation on such an ice cap reveals some characteristics feature, we measure high frequency dielectric property over the wide range of density, reflection and absorption characteristics and the specific resistance of the snow surface, in order to obtain fundamental data for analysing,

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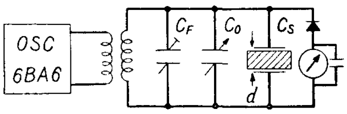
the electromagnetic wave propagation characteristics and for designing the antenna used on an ice cap. Furthermore we measure the fading characteristics at 300 Mc and 3000 Mc, in order to analyse the property of the radio duct which is brought about by the temperature reversal layer frequently formed in fine weather in the polar region. The directional pattern and the input impedance are measured by changing the heights of several types of model antenna above and below the snow surface. The above-mentioned data is not finished completely, because almost all the measurements that were made at Syowa Base are now being calculated, so that only a part of the results is reported here.

2. Methods and results of observation

The measurements of specific dielectric constant and dielectric loss ($\tan\delta$) in high frequencies are made by the tuning circuit resonance method illustrated in Fig. 1 for 1.5 Mc and 10 Mc, and by using the Lecher line illustrated in Fig. 2 for 100, 250, 300, and 3000 Mc.

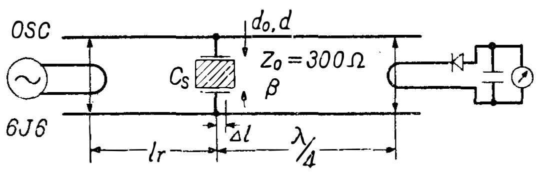


C_F: Frequency setting condencer
C_0 : Standard variable condencer capacity (C_S; $\varepsilon=1$)
C_S: Sample condencer
d : Gap of sample condencer

$$\varepsilon^*=(C_a/C_0)+1\,,\qquad \tan=\frac{C}{C_S}\left(\frac{1}{Q}-\frac{1}{Q_0}\right)$$

C_a: Increased of standard V. C. capacity with sample set up C_S

Fig. 1. The measurements circuits of specific dielectric constant and dielectric loss ($\tan\delta$) by resonance method for 1.5 Mc and 10 Mc Band.



$$\varepsilon = d/d_0$$

Change l_r,

$$\tan\delta=\frac{1}{\omega C_T Z_0}(1+\cot^2\beta l_r)\frac{\pi}{\lambda}\times(\Delta l-\Delta l_0)\frac{1}{\sqrt{n^2-1}}$$

Fig. 2. The measurements circuit of VHF specific dielectric constant and dielectric loss ($\tan\delta$) by Lecher wire for VHF Band.

Fig. 3 shows the change of high frequency specific dielectric constant ε^* with density of the snow and ice, and Fig. 4 shows the change of ε^* with the frequency.

The density of perpetual snow on the ice cap is about 0.3 and the snow apparently changes into an ice-like state at the density between 0.5 and 0.6. As is seen in Fig.

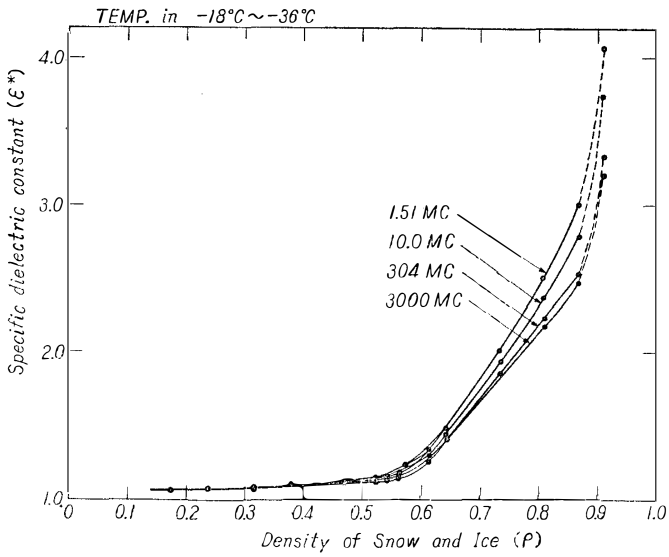


Fig. 3. The relation between density of the snow and ice to ε*.

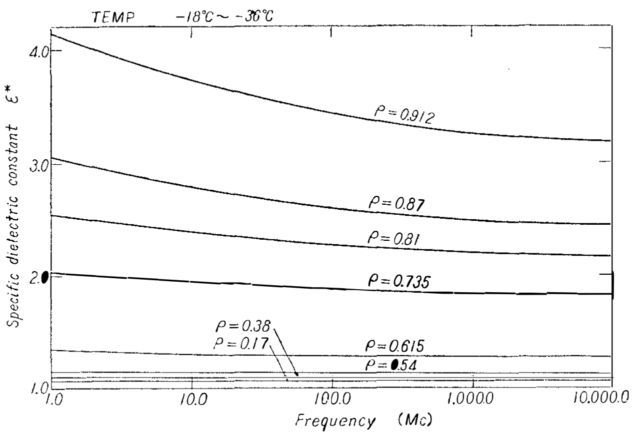


Fig. 4. The change of ε* with the frequency.

3, ε* does not depend on frequency before the snow takes its ice-like state and ε* takes a very small value not exceeding 1.1 because the microcrystals of snow are so weakly coupled and have a large air content. After snow reaches an ice-like state, ε* increases with the density and when the density is the same ε* is larger when the frequency is smaller, but the value of ε* does not exceed 4.0. There is a singular point in the curve of Fig. 3 when the snow changes into its ice-like state. As is seen from Fig. 4, ε* decreases with the frequency.

Fig. 5 shows the change of high frequency dicipation facter (tan δ) with frequency and Fig. 6 shows the change with density. It is seen from Fig. 5 that tan δ decreases rapidly as the frequency is increased, and it is shown in Fig. 6 that the dielectric loss increases with density.

From the above four figures the snow and ice composing the ice cap is shown to have an excellent insulating property for the electromagnetic waves of UHF or higher, and because the density of the perpetual snow near the surface is about 0.3 and so

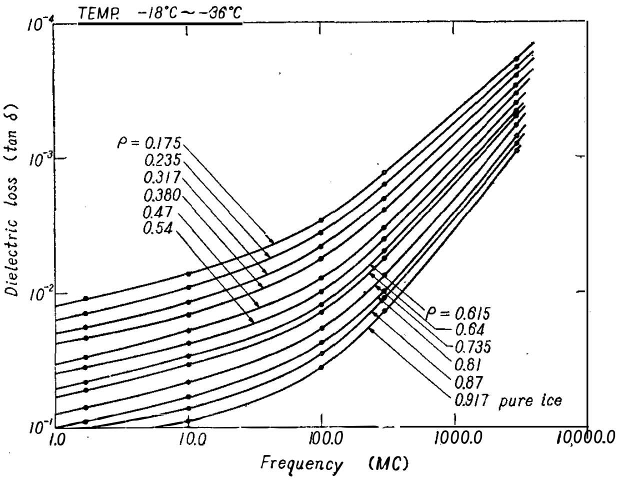


Fig. 5. The frequency characteristis of HF, VHF dielectric loss (tan δ) of ice cap snow and ice.

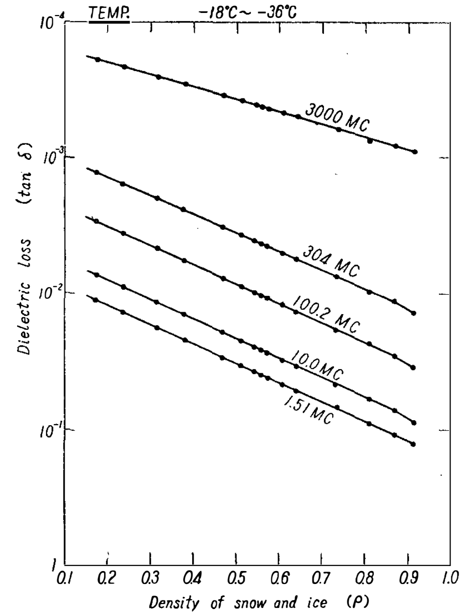


Fig. 6. The relation of the dielectric loss, increases with density of snow and ice.

ε^* amounts to 1.08 even for the HF range, it is supposed that the same radiation pattern as that in the free space would be obtained by merely putting a conducting line on snow surface which serves as a very simple antenna. We measure horizontal directional pattern, input impedance characteristic, and gain by setting a doublet antenna tuned for 100 Mc, and a 8 elements YAGI beam antenna tuned for 300 Mc, 3 meters above the snow surface, just on the snow surface, and 1 meter below. The results of the measurements are shown in Figs. 7–12.

From these figures it is found that the radiation characteristics are very similar

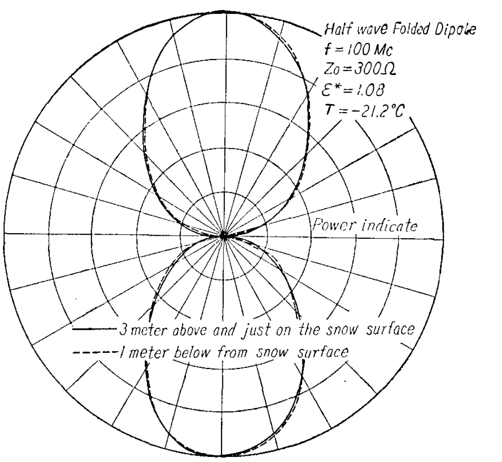


Fig. 7. The holizontal pattern of half wave Folded Dipole antenna for tuned 100 Mc, 3 meters above, 0 meter, 1 meter below the snow surface.

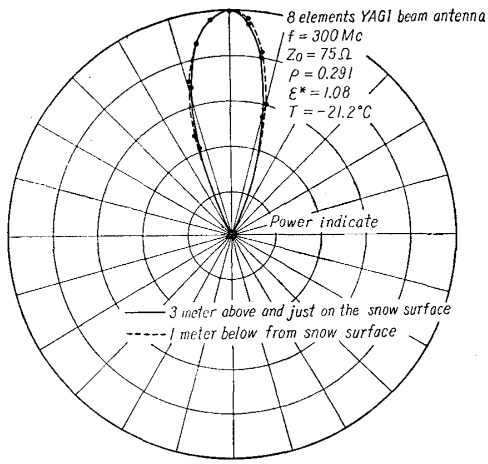


Fig. 8. The horizontal directional pattern of 8 elements YAGI beam antenna for tuned 300 Mc, 3 meters above, 0 meter, 1 meter below the snow surface.

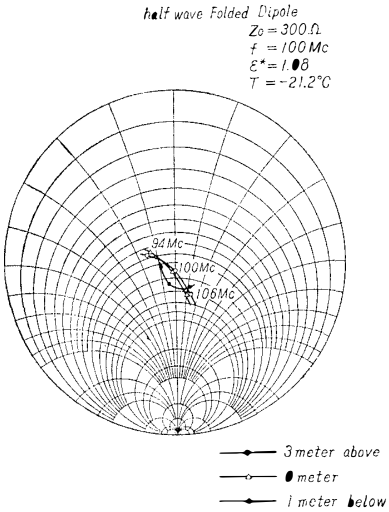


Fig. 9. The impedance characteristics of a half wave Folded Dipole antenna for tuned 100 Mc, 3 meters above, 0 meter, 1 meter below the snow surface.

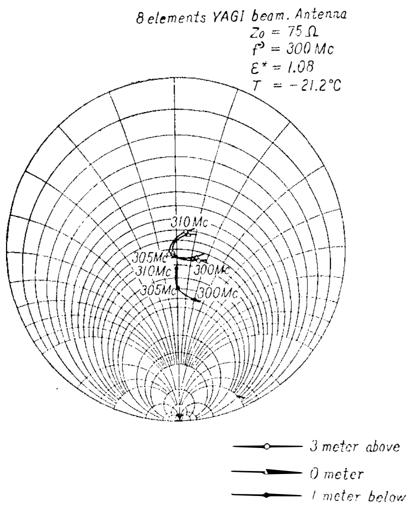


Fig. 10. The impedance characteristics of a 8 elements YAGI beam antenna for tuned 300 Mc, 3 meters above, 0 meter 1 meter below the snow surface.

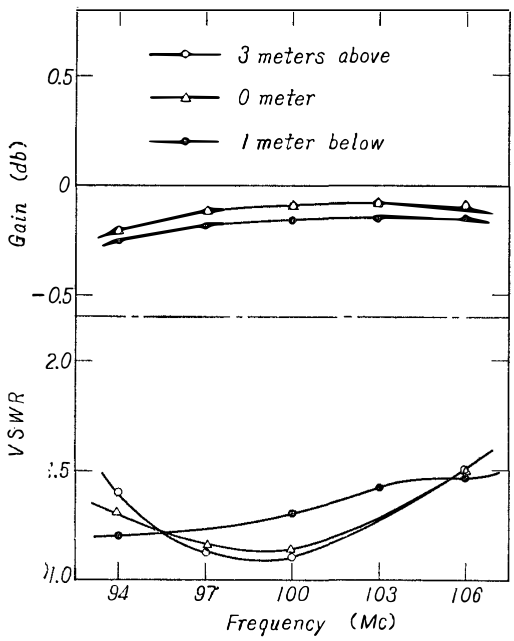


Fig. 11. The results of the measurements of input impedance and gain characteristic by a half wave Folded Dipole for tuned 100 Mc, 3 meters above, 0 meter, 1 meter below the snow surface.

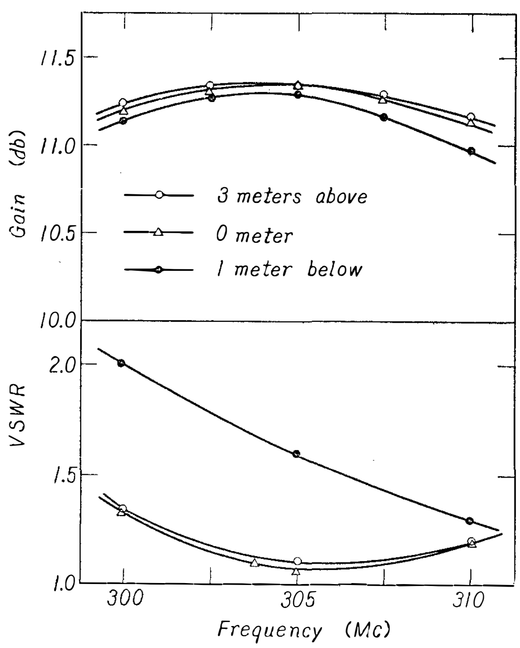


Fig. 12. The results of the measurements of input impedance and gain characteristic by a 8 elements YAGI beam antenna for tuned 300 Mc, 3 meters above, 0 meter, 1 meter below the snow surface.

to those in free space except the input impedance of the antenna set 1 meter below the snow surface.

When we made a 100 Km trip in autumn and a 350 Km trip in spring, we made contact between the mobile party and the base with GRC-9 in 5426 Kc by putting on the snow surface a rhombic antenna in autumn and rhombic, V type, doublet, and voltage feed zeppelin antenna in spring. We found that it is completely possible to make contact 350 Km off by this method which we think verifies our theory.

Further, we can recognize the existence of direct wave propagation by measuring the electric field strength when the wave is received in the interior of the continent less than 80 Km distant from the base and the rhombic antenna can be used effectively, but at a distance greater than 80 Km we can get a better result by using an antenna which radiates to a large angle realized by a doublet or zeppelin antenna to utilize ionospheric propagation.

On the other hand, a vertical polarization antenna requiring contact with the ground such as a whip antenna equipped on a snow car cannot be used because it cannot get a good grounding in the continent.

In fact it is difficult to tune a vertical antenna in an ice cap region and we can perform communication only within 40 Km.

3. Conclusion

We also get reflection and absorption coefficients by measuring the height pattern by the method shown in Fig. 13. The result of measurement will be reported in the near future.

The result of the measurement of the specific resistance of snow, and the result which shows the relation between fading characteristics of the 5 Km span in 300 Mc and 3000 Mc of the radio duct produced by a temperature reversal layer and the data of radio sonde, will also be reported on a forthcoming occasion.

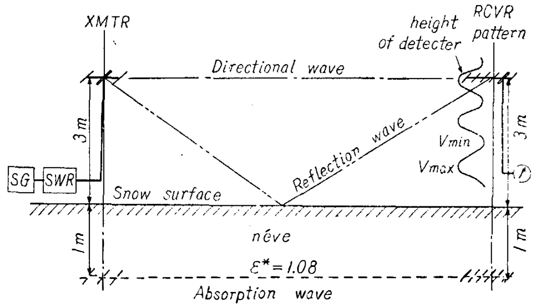


Fig. 13. The measurement of reflection coefficient on the snow surface by height pattern.

The dielectric property of the snow and ice composing an ice cap is revealed by this research work and at the same time the favorable antenna to be used is determined.

According to the experiment on propagation properties of an electromagnetic wave on the sea ice, the result is very similar to that on the sea water surface in VHF or lower, but it depends very much upon the state of the snow on sea ice in VHF or higher. It is favorable to make a polarizing plane horizontal on the ice cap and vertical on the sea ice.

Finally the author wish to express sincere thanks to the leader of our wintering party Mr. MURAYAMA and the other 12 members for their encouragement and co-operation.