Journal of Glaciology, Vol. 22, No. 88, 1979

INSTRUMENTS AND METHODS

PERFORMANCE OF V.H.F. AERIALS CLOSE TO A SNOW SURFACE

By C. S. M. DOAKE
(British Antarctic Survey, Natural Environment Research Council, Madingley Road, Cambridge CB3 0ET, England)

and M. GORMAN*
(Scott Polar Research Institute, Lensfield Road, Cambridge CB2 1ER, England)

ABSTRACT. Measurements of aerial admittance as a function of height above a snow surface show that when the surface temperature is below freezing, the aerial performance is insensitive to slight surface irregularities.

RÉSUMÉ. *Rendement des explorations aériennes v.h.f. sur une surface enneigée.* Des mesures aériennes d'admittance en fonction de la hauteur au-dessus de la neige montrent que lorsque la température de surface est négative, le rendement des explorations aériennes est insensible aux petites irrégularités superficielles.

ZUSAMMENFASSUNG. *Verhalten von Hochfrequenz-Antennen dicht über einer Schneefläche.* Messungen der Antennen-Leistung in Abhängigkeit von der Höhe über einer Schneefläche zeigen, dass leichte Unregelmässigkeiten der Oberfläche bei Temperaturen unter dem Gefrierpunkt keinen Einfluss auf die Antennen-Leistung haben.

WHEN operating ice-sounding radars on glacier surfaces it is necessary to have an idea of the effect of the dielectric boundary on the performance of the aerial. If, for example, the aerial impedance was a sensitive function of its height above a snow surface then this would have to be allowed for in the design of any experimental equipment and in the interpretation of results, because this would mean that variations in surface roughness of less than a wavelength would change the driving impedance and cause a mismatch with the transmitter/receiver, leading to "ringing" in the aerial feeder cable and reduced power performance.

It has been common practice to mount any aerial as high as practicable above the surface to remove as far as possible into the "far-field" region the change in permittivity seen by the aerial at the snow–air boundary. This also allows a small gain in power due to refraction (Robin and others, 1969). However, there are no published measurements of aerial characteristics near a snow–ice boundary to enable us to know how sensitive the system performance might be to changes in aerial height when used over rough or undulating surfaces.

We therefore measured the impedance of a 60 MHz aerial at a number of heights up to 90 cm above a snow surface on Devon Island ice cap, N.W.T., Canada, in June 1974. The aerial was made from 5 cm o.d. aluminium tube, as shown in Figure 1 and had a balun to match the unbalanced 50 Ω output of the receiver/transmitter to the balanced complex impedance of the aerial. The balun box was made from lumped elements and had adjustable inductors and capacitors. These were tuned with the aerial on the snow surface to give what appeared to be the best match at the centre frequency, and were left untouched thereafter. The admittances were measured on a General Radio 1602-B UHF admittance bridge using a Wayne Kerr SR 268 source/detector powered by dry batteries and connected to the aerial by 12.21 m of coaxial cable.

Values of the voltage standing-wave ratio (VSWR) at various frequencies, calculated by using Smith charts, are shown in Table I. The change of height is about 0.2 of a wavelength

* Now at University Engineering Department, Trumpington Street, Cambridge CB2 1PZ, England.

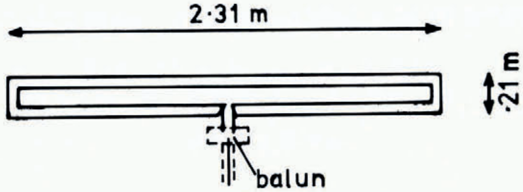

Fig. 1. Dimensions of 60 MHz aerial.

at 60 MHz. The VSWR values reflect the degree of mismatch between the transmitter/receiver and the aerial plus cable. A value of unity corresponds to the situation when all the transmitter power is absorbed by the aerial. For values greater than unity (and VSWR is defined so that this is always the case for imperfect matching) part of the transmitter power is reflected back from the aerial, decreasing the power absorbed by the aerial. It can be shown (see Appendix) that for a VSWR of 2 the two-way power loss which is seen as an apparent change in recorded echo strength is only 1 dB, and for a VSWR of 3 there is a power loss of 2.5 dB. The small differences between the VSWR values at varying heights are barely significant, and a more accurate experiment would be needed to determine whether the possible periodic behaviour at the centre frequency of 60 MHz is real. There is negligible change in echo strength at 60 MHz (less than 0.05 dB). Another way of interpreting the results would be to suggest that for this particular aerial design the variation of VSWR due to change in height is small compared with the variation with change in frequency. We take these results to confirm what is recognized in practice, that once the aerial impedance is properly matched, variations in height when close to the snow surface are unimportant.

TABLE I. VARIATION OF VSWR WITH HEIGHT ABOVE SNOW SURFACE

Frequency MHz	*Height of 60 MHz aerial above surface*				
	9 cm	27 cm	49 cm	70 cm	89 cm
50	2.2	3.0	3.3	3.2	2.9
55	1.35	1.55	1.7	1.7	1.7
60	1.15	1.02	1.13	1.02	1.01
65	1.8	1.6	1.55	1.55	1.6
70	1.9	1.75	1.65	1.8	1.9

The measurements reported here were carried out on a dry sunny day when the air temperature was around −10°C; night-time temperatures had fallen to around −20°C. In 1973, when sounding on Devon Island ice cap with a 440 MHz system, it was found that greater ice thickness could be penetrated at night than during the day. Presumably this was mainly because of increased dielectric absorption in the warmer surface layers in daytime, but may also be partly due to a change in aerial performance. There appear to be no measurements relating aerial performance to snow surface temperatures, although it has been noticed that wet snow can cause a bad mismatch on a 60 MHz aerial previously tuned over dry snow (private communication from H. Thompson). A dipole antenna 30 m long with resistive loading for use on the temperate ice of Vatnajökull was designed by considering the aerial to be radiating into a medium of uniform permittivity with a value equal to the harmonic mean of the permittivities of ice and air (Ferrari and others, 1976). The aerial was successfully operated over wet snow, showing that a different permittivity layer which is thin compared to the wavelength does not materially affect the performance. However because the length was much greater than the amplitude of surface roughness, the aerial was effectively on the boundary of a smooth surface and this situation is not strictly analogous to that at higher radio frequencies where the surface roughness is greater compared to the wavelength; also the permittivity of the snow depends on its density (Robin and others, 1969), which near the surface often varies rapidly with depth in polar regions, where the higher frequencies are normally used.

Acknowledgements

We thank Dr M. E. R. Walford for the loan of the Wayne Kerr source/detector, and Dr W. S. B. Paterson for the opportunity to visit Devon Island and for his support there. The work was carried out as part of a programme undertaken by the Scott Polar Research Institute with cooperation from the British Antarctic Survey and from the Polar Continental Shelf Project, Department of Energy, Mines and Resources, Canada, which provided logistic support. We would also like to thank Drs S. Evans and G. de Q. Robin for their valuable comments.

MS. received 6 May 1977 and in revised form 12 August 1977

APPENDIX

The power loss caused by a mismatch at the end of a transmission line, i.e. when it is not terminated by its characteristic impedance, may be calculated by considering the amplitudes of the forward and reflected voltages. If the characteristic impedance of the line is Z_0 and the amplitudes of the forward and reflected waves are A and B respectively, then the forward power P_f and the reflected power P_r are given by

$$P_f = A^2/2Z_0; \qquad P_r = B^2/2Z_0.$$

The power dissipated in the load P_d is given by

$$\begin{aligned} P_d &= P_f - P_r \\ &= P_f(1-\rho^2), \end{aligned}$$

where $\rho = B/A$ and is called the reflection coefficient. The VSWR is related to ρ by (see Kennedy, 1970, p. 673)

$$\text{VSWR} = (1+\rho)/(1-\rho).$$

Denoting VSWR by S, the power loss P_L is given (in decibels) by

$$\begin{aligned} P_L &= 10 \log_{10} (P_d/P_f) \\ &= 10 \log_{10} (1-\rho^2) \\ &= 10 \log_{10} [4S/(1+S)^2]. \end{aligned}$$

When the same aerial is used for both transmitting and receiving, there will be twice the power loss, which is then given by $20 \log_{10} [4S/(1+S)^2]$. This is the formula used to calculate the change in echo strength due to a variation in VSWR.

REFERENCES

Ferrari, R. L., *and others*. 1976. *The 1976 Cambridge–Reykjavik Universities Expedition to Vatnajökull, Iceland*, [*by*] *R. L. Ferrari, K. J. Miller, G. Owen*. Cambridge, University of Cambridge. Dept. of Engineering. (Special Report 5.)

Kennedy, G. 1970. *Electronic communications systems*. Tokyo, McGraw-Hill Kogakusha Ltd.

Robin, G. de Q., *and others*. 1969. Interpretation of radio echo sounding in polar ice sheets, by G. de Q. Robin, S. Evans, and J. T. Bailey. *Philosophical Transactions of the Royal Society of London*, Ser. A, Vol. 265, No. 1166, p. 437–505.