# 2018 MCM

**Problem A: Multi-hop HF Radio Propagation**

**Background:** On high frequencies (HF, defined to be 3 – 30 mHz), radio waves can travel long distances (from one point on the earth’s surface to another distant point on the earth’s surface) by multiple reflections off the ionosphere and off the earth. For frequencies below the *maximum usable frequency* (MUF), HF radio waves from a ground source reflect off the ionosphere back to the earth, where they may reflect again back to the ionosphere, where they may reflect again back to the earth, and so on, travelling further with each successive hop. Among other factors, the characteristics of the reflecting surface determine the strength of the reflected wave and how far the signal will ultimately travel while maintaining useful signal integrity. Also, the MUF varies with the season, time of day, and solar conditions. Frequencies above the MUF are not reflected/refracted, but pass through the ionosphere into space. In this problem, the focus is particularly on reflections off the ocean surface. It has been found empirically that reflections off a turbulent ocean are attenuated more than reflections off a calm ocean. Ocean turbulence will affect the electromagnetic gradient of seawater, altering the local permittivity and permeability of the ocean, and changing the height and angle of the reflection surface. A turbulent ocean is one in which wave heights, shapes, and frequencies change rapidly, and the direction of wave travel may also change.

# Problem:

**Part I:** Develop a mathematical model for this signal reflection off the ocean. For a 100-watt HF constant-carrier signal, below the MUF, from a point source on land, determine the strength of the first reflection off a turbulent ocean and compare it with the strength of a first reflection off a calm ocean. (Note that this means that there has been one reflection of this signal off the ionosphere.) If additional reflections (2 through n) take place off calm oceans, what is the maximum number of hops the signal can take before its strength falls below a usable signal-to- noise ratio (SNR) threshold of 10 dB?

**Part II:** How do your findings from **Part I** compare with HF reflections off mountainous or rugged terrain versus smooth terrain?

**Part III:** A ship travelling across the ocean will use HF for communications and to receive weather and traffic reports. How does your model change to accommodate a shipboard receiver moving on a turbulent ocean? How long can the ship remain in communication using the same multi-hop path?

**Part IV:** Prepare a short (1 to 2 pages) synopsis of your results suitable for publication as a short note in *IEEE Communications Magazine*.

Your submission should consist of:

* One-page Summary Sheet,
* Two-page synopsis,
* Your solution of no more than 20 pages, for a maximum of 23 pages with your summary and synopsis.
* Note: Reference list and any appendices do not count toward the 23-page limit and should appear after your completed solution.

2018年MCM

问题A：多跳HF无线电传播

背景：在高频（HF，定义为3 - 30 mHz），无线电波可以通过离开电离层和离开地球的多次反射而行进很长距离（从地球表面上的一个点到地球表面上的另一个远点） 。对于低于最大可用频率（MUF）的频率，来自地面源的HF无线电波将电离层反射回地球，在那里它们可能再次反射回到电离层，在那里它们可能再次反射回地球，等等，随着每个连续的跳跃继续前进。除了其他因素之外，反射表面的特性决定了反射波的强度以及信号最终行进的程度，同时保持有用的信号完整性。而且，MUF随季节，一天中的时间和太阳能条件而变化。 MUF以上的频率不被反射/折射，而是通过电离层进入太空。在这个问题上，重点是特别关注海洋表面的反射。从经验上发现，在一个平静的海洋上，反射出湍流的海洋的反射比衰减更多。海洋湍流将影响海水的电磁梯度，改变海洋的局部介电常数和渗透率，改变反射面的高度和角度。汹涌的海洋是波浪高度，形状和频率迅速变化的地方，波动的方向也可能发生变化。

问题：

第一部分：为海洋信号反射建立一个数学模型。对于一个100瓦的HF恒定载波信号，低于MUF，从陆地上的一个点源，确定从一个湍流海洋的第一反射的强度，并与平静海洋的第一反射的强度进行比较。 （注意，这意味着这个信号离开电离层有一个反射。）如果在平静的海洋附近发生附加的反射（2到n），那么信号在强度低于可用的信噪比（SNR）阈值为10 dB？

第二部分：第一部分的研究结果与高山或崎岖地形与光滑地形的HF反射比较如何？

第三部分：穿越海洋的船舶将使用HF进行通信，并接收天气和交通报告。您的模型如何改变以适应在动荡的海洋上移动的船上接收器？船舶能够使用相同的多跳路径保持多久？

第四部分：在IEEE通信杂志上准备一份简短的（1到2页）摘要，以便作为短信发布。

您的提交应该包括：

•单页汇总表，

•两页简介，

•您的解决方案不超过20页，最多23页，内容摘要和摘要。

•注意：参考列表和任何附录不计入23页限制，应在完成解决方案后出现。